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THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

I. THE DISTRIBUTION OF RADIATION IN A WATER PHANTOM*

By G. FAILLA, D.Sc., E. H. QUIMBY, M.A., L. D. MARINELLI, B.S., *and* J. E. ROSE

Biophysical Laboratory, Memorial Hospital

NEW YORK CITY

INTRODUCTION

IT HAS been known for a long time that roentgen rays on passing through a material medium undergo changes in quality as well as in intensity. The quality or hardness difference between the incident beam and the emergent beam depends on several factors, but primarily on the spectral distribution of the radiation in the incident beam, the atomic constituents of the medium, and the thickness of the material traversed.

The practical importance of filtration in radiation therapy has tended to emphasize the *hardening* of roentgen rays by passing them through an absorbing medium (the filter in this case), but it should be remembered that the reverse process may also take place under certain conditions. In other words, a beam of radiation may be *less penetrating* (softer) after traversing an absorbing medium than it was initially. Which one of these two processes will predominate in any given case depends on the factors enumerated above. Starting with a very heterogeneous beam of roentgen rays (e.g. "unfiltered" roentgen rays), the interposition of a copper filter will harden the radiation very considerably. But passing this filtered beam through a block of paraffin will not make it harder, but, on the contrary, will decrease its penetrating power materially. Human tissues affect roentgen rays similarly, and therefore the quality of radiation is different at different tissue depths.

Physicists familiar with radiological problems have had in mind the softening of roentgen rays by tissues as one of the factors to consider in the study of the distribution of radiation within the human body. The discovery of the Compton effect some years ago directed attention to this problem, but nevertheless, no quantitative data have been available until recently.[8,9] Even now a great deal remains to be done. The practical importance of definite knowledge on this subject is obvious from the following considerations:

With the establishment of the international unit for the measurement of roentgen rays, the roentgen, we are now in a position to express in this unit the amount of radiation emitted by a roentgen tube in

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a given time, under conditions which may be duplicated anywhere. This can be done by means of a standard ionization chamber which fulfills the conditions stipulated in the definition of the roentgen. This chamber, however, can only be used for measurements made "in air." If we desire to determine the amount of radiation administered to the surface of a patient's skin in a given treatment, we must resort to the use of a small ionization chamber of the "thimble" type. Such an ionization chamber placed over the skin is affected principally by: (1) roentgen rays which originate from the target of the tube—"direct radiation"—and (2) roentgen rays which originate in the volume of tissue traversed by the primary beam—"scattered radiation." The quality of the two components is not the same, the scattered radiation being softer than the primary, or direct, radiation. Before we can say that the small chamber measures the amount of radiation falling on the patient's skin, *in roentgens*, we must be sure that the ionization chamber has no "wall effect" for a range of wave-lengths sufficiently broad to include the minimum wave-length in the primary beam and the practical maximum wave-length of the scattered radiation.* This can be done only by comparing the small chamber with the standard air chamber under proper conditions throughout the range just mentioned.

Many practical difficulties militate against a direct comparison of this sort. It is evident, however, that in the first place, we must gather some information on the change in wave-length which the primary radiation undergoes in the process of scattering under the conditions which obtain in radiation therapy. For the purpose in view this change in wave-length need not be determined quantitatively in Ångström units. It is sufficient to know how far in the wave-length range the comparison of the small chamber with the standard chamber must be carried. This can be done by indirect means. If then we can construct a small chamber which has no wall effect within the required range (and meets certain other requirements) we shall be able to measure *in terms of the roentgen* the quantity of roentgen rays reaching a patient's skin both from the roentgen tube and from the underlying tissues.

The difficulties stated above are present, but to an even greater degree, in the measurement of the amount of radiation reaching a given tissue (or water phantom) depth, when we wish to express this also in roentgens. Obviously it is desirable to do so in order that the correlation of "tissue doses" and observed effects may be put on a less empirical basis than it is at present.

Our remarks so far refer specifically to the roentgen rays usually employed in cancer therapy, that is, roentgen rays produced at voltages of 125 to 220 kv. In general, they apply equally well to higher voltage roentgen rays and to gamma rays. The fact that at present there is considerable uncertainty about the measurement of these quantities *in roentgens*, even in air, does not make the determination of the quality changes within the irradiated tissues less desirable. But, of course, the problem must be envisaged from a somewhat different point of view.

In a recent paper from this laboratory, Quimby and McNattin[8] presented the results of experiments dealing with the change in quality of 200 kv. roentgen rays due to scattering by paraffin. Since these experiments have a direct bearing on the present study, it may be well to give a brief summary of the work. The quality of a beam of roentgen rays may be expressed reasonably well* by an absorption curve determined under proper conditions. The quality of the roentgen rays reaching a point within a mass of tissue (water or paraffin) *from all directions* may also be expressed by an absorption curve obtained in

* Certain other requirements must be met also, but they are not pertinent to the present discussion.

* The best method of determining the quality of a beam of roentgen rays is the spectrometric one, but it is not applicable to the problem under consideration.

the following manner: A "small" spherical ionization chamber, preferably made of organic materials, is placed at the point in question. Readings are then taken with this chamber "bare" and covered successively by increasingly thicker spherical shells of a suitable absorbing material, such as copper. The data thus obtained may be plotted as an absorption curve. It should be noted at this point that the quality of the radiation entering the chamber from different directions is different, and that, therefore, the absorption curve obtained in this manner represents the "average" quality of the radiation reaching the chamber from all directions.

An an example of the results obtained by Quimby and McNattin, we may mention that the quality of 200 kv. roentgen rays initially filtered by 0.5 mm. Cu is altered to such an extent by repeated scattering within a large paraffin block that at 10 cm. depth the average quality of the radiation reaching the chamber is very nearly the same as that of 200 kv. roentgen rays filtered by 0.1 mm. Cu. In other words, the degree of "softening" brought about by scattering in the paraffin block, under the conditions of the experiment, is substantially the same as would be obtained in the primary beam in air by decreasing the filter from 0.5 to 0.1 mm. Cu. Considering that this work was done with a "thin-walled" Coolidge roentgen tube (of the old soft glass type) the change in the quality is the more striking. A considerable change in quality was also found when the ionization chamber was placed on the surface of the paraffin block.

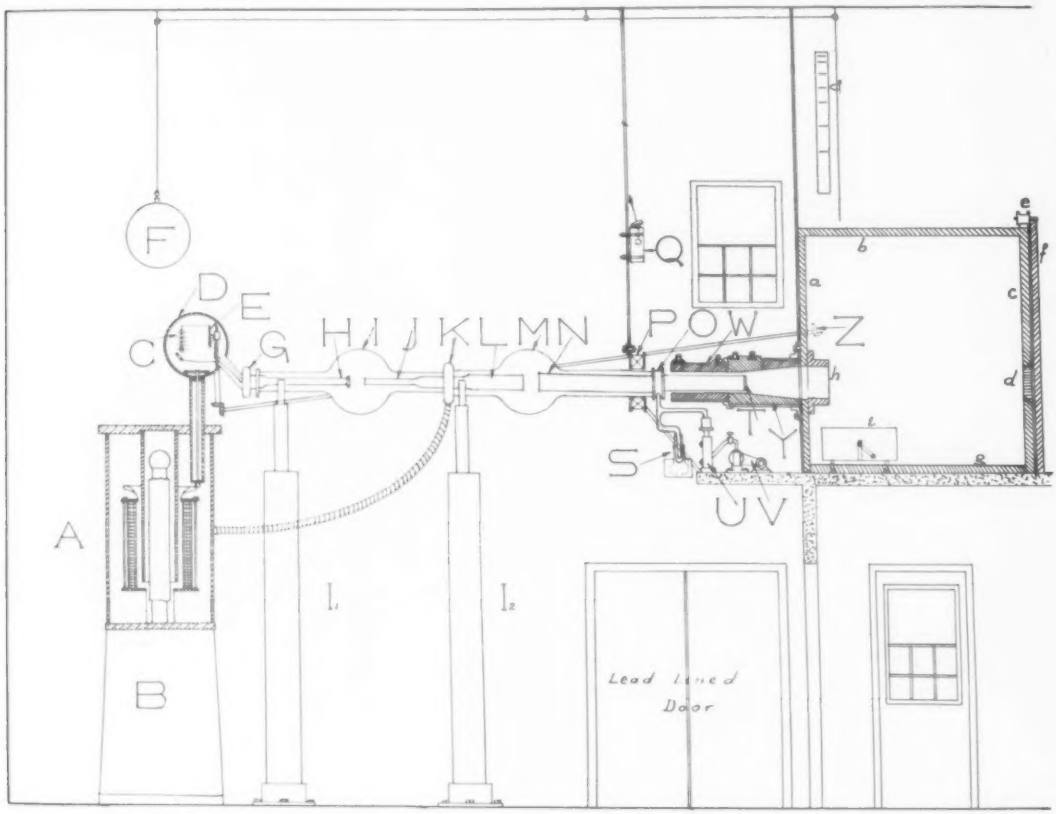
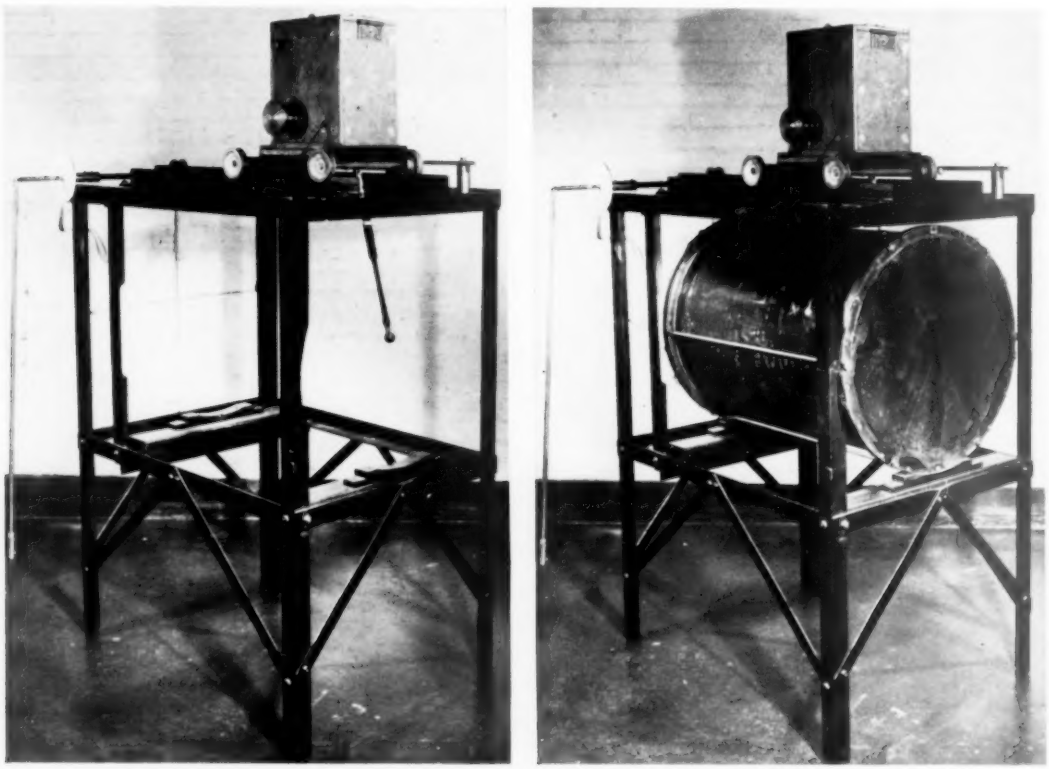


Fig. 1. Diagram of 700 kv. roentgen tube set-up.

In the work just discussed, no attempt was made to determine percentage "depth doses" with the apparatus used because the

ionization chamber with the removable copper shells was too big for this purpose. In view of the difference in quality found between the radiation at the surface and the radiation at a 10 cm. depth, it becomes necessary to investigate the influence which this may have on the depth dose as ordinarily determined. On theoretical grounds the difference in quality just mentioned should be different for roentgen rays of different wave-lengths. Accordingly it is of interest to extend the investigation to roentgen rays of higher voltage than 200 kv. and to gamma rays.



(*a*) (*b*)

FIG. 2. Horizontal water phantom set-up. (*a*) Tank removed to show ionization chamber. (*b*) Tank in position.

APPARATUS

Water Phantom. At the outset it was decided to make the experiments with the three qualities of radiation under as nearly comparable conditions as possible. Since the tube capable of operation at 350 to 850 kv. (Fig. 1) produces a roentgen-ray beam utilizable only in a horizontal direction, the water phantom (Fig. 2) for the experiments had to be of the horizontal type. This has the disadvantage that for the "zero depth" or surface measurements the ionization chamber had to be completely submerged. However, measurements were also made in a "vertical phantom" in the case of 200 kv. roentgen rays and gamma rays, with the ionization chamber under different degrees of submergence. Another difficulty with the horizontal phantom is that there must be some retaining "wall" between the chamber and the source of radiation, which may influence to some extent the results obtained. To minimize as much as possible the effect of the phantom wall, it was decided to use for this purpose animal skins ordinarily used as drum heads. However, in spite of the liberal use of shellac to waterproof the skins, water gradually seeped into the skins proper, and considerable stretching and bulging occurred. This was particularly objectionable since it became gradually worse during the course of one experiment and changed

the thickness of water traversed by the rays. Choosing the lesser of two evils, it was finally decided to support the drum head on the incidence side of the phantom by a sheet of celluloid 2 mm. thick. All water phantom measurements, therefore, were taken through 2 mm. of celluloid and the 1 mm. of animal skin painted with shellac.

For theoretical reasons which will not be discussed in this paper, the water phantom was made quite large, 44 cm. in diameter and 60 cm. long. The mass of water coming under the influence of the radiation was therefore considerably larger than the mass of irradiated tissues in a patient. This has some influence on the applicability of the experimental results to radiation therapy, but is of no consequence for our present purpose. The body of the phantom was made of a special bakelite tube 5 mm. thick, kindly supplied by the General Electric Company. (It was thought desirable not to use a metal container.)

Ionization Chambers. In the experiments of Quimby and McNattin, one ionization chamber was used, and the quality of the radiation at different depths was studied by adding copper filters around the ionization chamber. This procedure is not quite suitable for the present investigations, where the range of radiation qualities is so large. Accordingly it was decided to use chambers of approximately the same (internal) volume, but made of different materials, and different thicknesses of the same material. Four materials were used: celluloid, aluminum, copper, and lead. The greatest thickness of any one material was 3.5 mm. Due to the methods of manufacture of the chambers, their thicknesses are known only approximately. This is of no great moment in our present discussion. After the work with these chambers has been completed, we are planning to disassemble them for the purpose of measuring their thicknesses more accurately.

The shape of an ionization chamber suitable for water phantom work is of considerable importance. The chamber must be such that it has no directional error. That is, the reading must be independent of the aspect of the chamber towards the beam of radiation, or its orientation. The ideal shape is spherical, without a protruding stem. Since, however, the chamber* must be attached to a current measuring device, this is practically impossible. The practical solution is to make the chamber spherical and the connecting stem as small in diameter as possible. In our case the internal diameter of the chambers was (very nearly) 1.5 cm., and the diameter of the stem about 0.48 cm. (see Fig. 3 for the relative sizes).

It was thought desirable to use one chamber made of a light, non-metallic material, with very thin walls. Such a chamber may be constructed very simply in the following manner: A spherical "lemon drop" (consisting largely of sugar) is attached to a tube of the external diameter which it is desired the stem of the chamber shall have. To do this, the tube is heated and is then inserted into the lemon drop. The size of the sphere may now be reduced at will by spinning in a lathe and holding a wet cloth against the lemon drop so as to dissolve some sugar evenly in all directions. After the ball is dry, it is dipped in an acetone solution of celluloid, making sure that a uniform coating of celluloid is left on the ball, and on part of the attached tube, so as to form at the same time the stem of the chamber. The thickness of the celluloid layer depends on the concentration of the celluloid in the acetone solution and on the number of coats applied to the ball. After the celluloid is dry, the sugar may be dissolved out by running water into the tube attached to the ball by means of another tube of smaller diameter. In this way, chambers of any desired

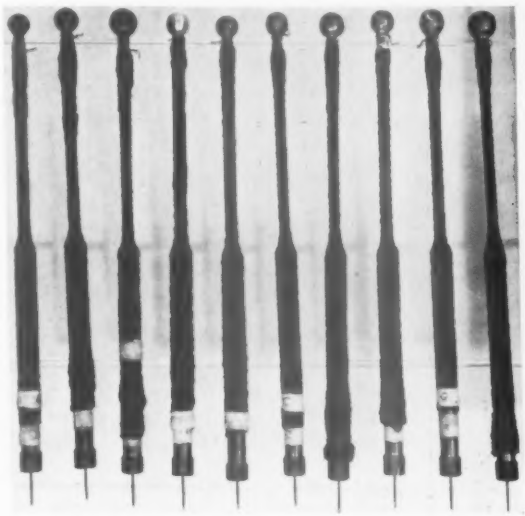


Fig. 3. Small ionization chambers of different materials.

* The small spherical, detachable chambers developed by Sievert would introduce serious complications in carrying out the experiments.

thickness may be made. The inner surface of the chamber is then coated with India ink to make it sufficiently conducting.

The metal chambers were spun in a lathe. The same chuck was used for all, but, owing to the different resilience of the materials used, there is probably some variation in the inside diameters of the chambers, and the wall thicknesses cannot be estimated with high precision. Also some of the chambers are not exactly spherical. It will be seen later that these variations are of no particular significance in our present study. The geometrical characteristics of all the chambers are given in Table 1, with the reservations just noted.

TABLE I

SPECIFICATIONS OF IONIZATION CHAMBERS

Chamber	Material	Inside Diameter cm.	Wall Thickness mm.
H	Celluloid	1.52	0.2 (?)
A	Celluloid	1.52	1.4
I	Celluloid	1.52	3.4
B	Aluminum	1.52	0.4
C	Copper	1.52	0.3
D	Copper	1.52	1.2
J	Copper	1.52	0.6
E	Lead	1.52	0.5
F	Lead	1.52	0.8
G	Lead	1.52	1.1
K	Lead	1.52	3.7

The inner electrodes of all the chambers are alike. A very fine piano wire (0.14 mm. in diameter) was used for the conductor through the stem of the chamber. One end of this wire was made to protrude through the amber insulating bushing into the spherical chamber for a distance of about 1 cm. It was then coated repeatedly with a mixture of celluloid, graphite, and acetone, to form the chamber electrode of a diameter of about 2 mm. To insure good conductivity the electrode was also coated with India ink.

Measuring Instrument. The ionization currents produced in chambers of such small volume with ordinary sources of roentgen rays, and particularly with the available radium, are very small. Accordingly a very sensitive measuring instrument is essential for the proper carrying out of the comparison. The range of the instrument must also be very large because some of the readings to be taken are only a small fraction of other readings in the same series. Furthermore, in view of the long time required for the investigation, complete protection of the experimenter from the radiation (especially gamma rays and 700 kv. roentgen rays) is essential. A vacuum tube instrument was designed and constructed for this purpose which fulfilled all the requirements in a very satisfactory manner. The principle of this instrument has been described in previous publications.[4,5] The wiring diagram of the one used in these experiments is given in Figure 4, and a photograph of the set-up is shown in Figure 5. With this arrangement it is possible to take a large number of readings in a relatively short time, while the operator is in a separate room at any desired distance from the source of radiation.

The measuring instrument proper consists of two parts: A lead box containing the vacuum tube (known as FP-54), the high resistance or radium compensator, and the grounding key. The ionization chamber is attached to the bottom of this lead box by means of its highly insulated stem, as shown in Figure 2 (where the lead box is seen mounted on the water phantom frame). Thus the delicate parts of the apparatus are mounted compactly and rigidly together. Provision is made for shifting the position of this unit in a horizontal direction by any desired amount, from outside the roentgen room, without stopping the x-ray machine. This is accomplished by means of a rack and pinion arrangement and a dial graduated in centimeters. Accordingly readings can be taken at different distances from the source, or at different depths in water, without interruption.

The second part of the measuring device contains the batteries, rheostats, meters, etc., required for the operation of the vacuum tube and the control of the circuit. This unit is placed outside of the roentgen room in a protected place, where it is most convenient for the operator to conduct the experiments. The two parts of the instrument are connected together by a multi-conductor cable with proper shielding.

Two of the roentgen machines used in the course of the experiments are provided with control ionization chambers connected to sensitive galvanometers. With this arrangement the roentgen machine may be adjusted to give the same radiation throughout the course of an experiment and from day to day, without having

to rely entirely on the milliammeter and the primary voltmeter readings. A standard cell, a high resistance, and a galvanometer shunt, are provided for the calibration of the control instrument. This device was found invaluable in the operation of the high voltage tube (350 to 700 kv.) since its output is apt to fluctuate considerably.

Sources of Radiation. The sources of radiation were as follows: (1) Two mechanical rectifier roentgen machines of the usual deep therapy type, operating water-cooled Coolidge tubes* at 200 kv. and 30 ma. The voltage is measured by a spark gap with 12.5 cm. spheres. (2) The cascade tube designed by Coolidge, Dempster and Tanis,[1,2] for operation at a maximum of 900 kv. (Fig. 1), which was kindly loaned to the hospital by the General Electric Company about a year ago. The high voltage generator for this outfit is a special induction coil with mercury interrupter to which is applied 60 cycle alternating current at a maximum of 1100 volts. The tube voltage is measured by a spark gap with 50 cm. spheres, one of which is grounded. This tube is equipped with a "transmission" target, and on this account the useful beam of radiation must always traverse a fixed filter equivalent to about 5 mm. of copper. (3) The third source of radiation consists of 4 grams of radium in a heavy lead container, known as the "pack." For details of the construction of this apparatus, which may have a bearing on the present work, the reader is referred to an earlier publication.[3] For the present it may suffice to state that the "radiating surface" is

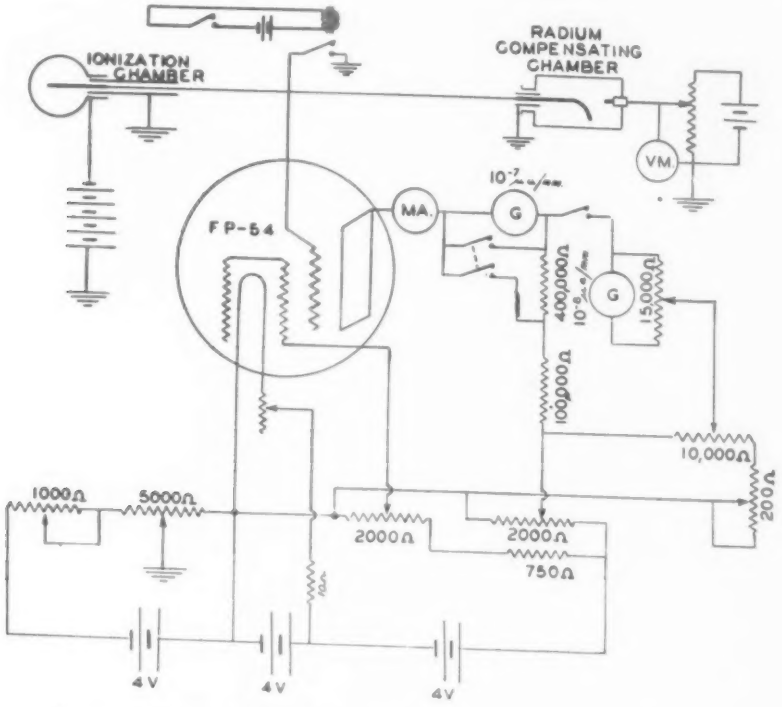


Fig. 4. Wiring diagram of vacuum tube measuring instrument.

7.5 cm. in diameter and is studded with 40 platinum tubes, each containing 100 mg. of radium, placed perpendicular to the surface. This arrangement, which is desirable from certain points of view, introduces an uncertainty in the filtration. We may say, however, that the average primary filter is equivalent to 2 mm. of lead. As a secondary filter, a disk of bakelite 6 mm. thick was used in the experiments. The radium is surrounded in all directions by about 10 cm. of lead, except for the conical port through which the useful beam passes. The brim of this port is 10 cm. in diameter, in a plane parallel to the radiating surface and 6 cm. from the *center* of the radium tubes.

* These tubes are made of hard glass of a thickness of several millimeters at the bulb.

EXPERIMENTS

Preliminary tests were made to ascertain the saturation voltage required with each ionization chamber and each source of radiation. The possible influence of the direct and scattered radiation on the measuring instrument (other than in the small ionization chamber) was also investigated. No corrections had to be made on this account. Leakage of charge from the collecting electrode of the chamber was obviated entirely by the provision of guard rings and the use of the null method of measurement. The (saturation) voltage was applied to the spherical shell of the chamber, while the inner electrode was always maintained at practically ground potential. This eliminates also trouble from the well-known "soaking effect" which is always present to some degree in electroscopic instruments. A grounded metal guard ring was provided between the charged shell of the chamber and the inner electrode. This metal guard extended continuously from the ionization chamber to the grid of the vacuum tube, to avoid the possibility of leakage at any point. For measurements in the water phantom, it was found more convenient to charge the water to the saturation voltage of the chamber. For this reason, the metal stem of the chamber, which had to be grounded in order to serve as a guard ring, was covered with insulating rubber tape.

With 700 kv. roentgen rays, readings were taken under the following conditions: Filter equivalent to 5 mm. copper; initial target-to-center-of-chamber distance, 67 cm.; irradiated field, 4.5×4.5 cm. at initial target-chamber distance. In air, the position of the chamber was shifted from 0 (initial point) to 2, 4, 8, 15, 25, 35 cm. Then the irradiated field was changed successively to 6.7×6.7 cm., 11×11 cm., and 20×20 cm., each time taking readings for the above settings of chamber distance. Corresponding readings were obtained with each chamber of Table 1.

Following this, the phantom was mounted in place and the whole series of experiments was repeated with each chamber in water. In this

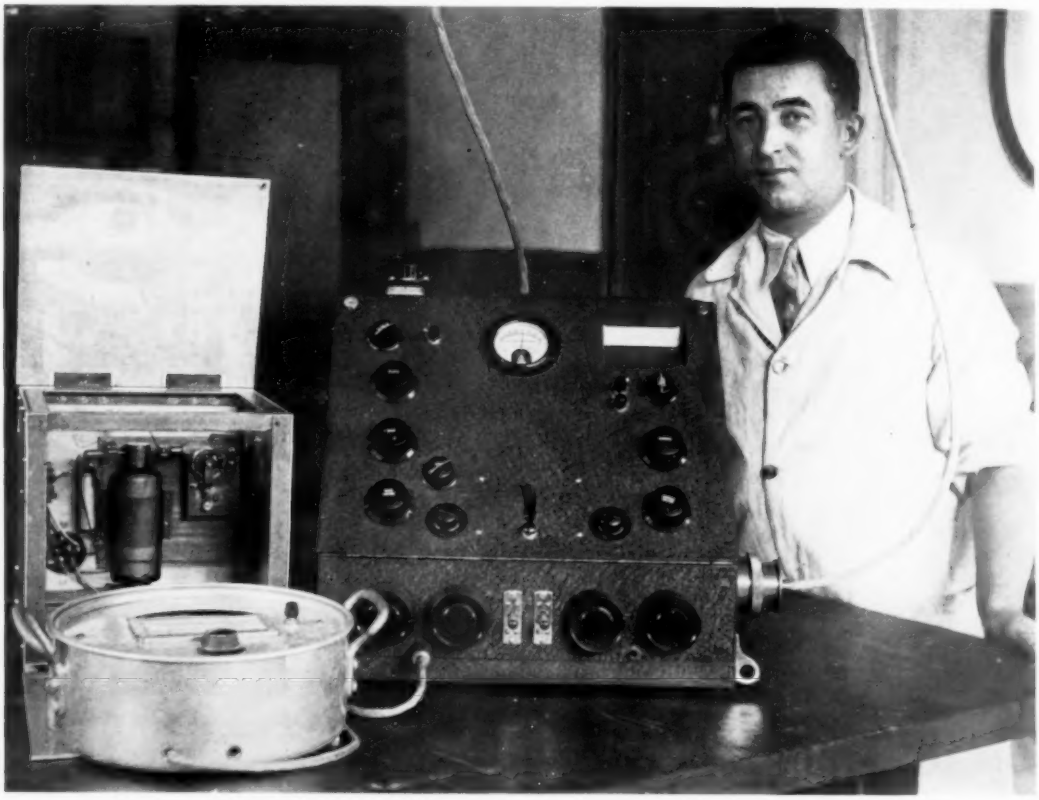


FIG. 5. Vacuum tube measuring instrument.

case the initial position of the center of the chamber was always very nearly 9 mm. from the drum head (or surface of the water). This means that in the case of the thinner chambers there was a thin layer of water in front of the chamber when it was at its zero position. Accordingly the thicker chambers, such as I, were "just submerged," while the thinner ones were at a slightly greater depth when in the surface, or zero, position.

The work with 700 kv. just described was duplicated with the tube operating at 600, 500, and 350 kv. successively.* Since the filter forms an integral part of the tube in this type of apparatus, the same filtration (equivalent to 5 mm. of copper) was used throughout.

In addition, "linkage" experiments were carried out in which only one of the factors was varied rapidly, so as to have key readings under as nearly identical conditions as possible. For instance, in one such experiment, readings were taken with all the ionization chambers in quick succession, maintaining all the other factors constant.

The work with 200 kv. roentgen rays involved the use of a vertical phantom in addition to the horizontal one. For purposes of direct comparison, the results given in this paper, however, are those obtained with the horizontal phantom which was used with the other two sources of radiation. While the tube voltage was maintained at 200 kv. the filter was varied from 0 to a maximum of 3.42 mm. of copper. Thus a large number of readings had to be taken, extending over a considerable time. Accordingly, "linkage" experiments were made in this case also.

A corresponding set of experiments was carried out with the radium pack as a source of gamma rays. In this case, however, the field area could not be controlled readily, and no attempt was made to vary the cross-section of the beam which emerges from the conical port of the lead container. The filter, equivalent to 2 mm. of lead, was kept constant. On the other hand, since distance plays a more important part in this case, the experiments were carried out at three different distances: 8.8, 13.8, and 18.8 cm., from the center of the radium container to the center of the ionization chamber.

* The actual sequence of the experiments was somewhat different from the one given here for the sake of brevity. This, of course, is immaterial.

RESULTS

The data obtained in the course of the above experiments are so numerous that it is inadvisable to present and discuss them completely in this paper. Accordingly some of the practical results only will be given.

Depth Doses. In Table II are given the results obtained with some typical ionization chambers, using the horizontal water phantom and three qualities of radiation, the data being reduced by calculation to the same target- (or radium-) skin distance of 50 cm. This reduction introduces no appreciable error in the depth doses for 200 and 700 kv. roentgen rays, because the target distance at which the measurements were made (67 cm.) is not very different from 50 cm. Furthermore, check measurements were made with 200 kv. roentgen rays, using some of the chambers and the 50 cm. distance. The irradiated field of 400 sq. cm. (20 × 20 cm.) stated in the table refers to the surface of the water at 50 cm. from the target.

In the case of the depth doses for the pack, reduced to a 50 cm. distance, the extrapolation may have introduced an appreciable error, since the experimental data were obtained at distances of 8, 13, and 18 cm. However, this is immaterial, since in practice it is out of the question to use radium at a distance of 50 cm. Whatever error may have been introduced by the extrapolation to the 50 cm. distance cannot be large, because the same method of calculation applied to the three experimental distances (8, 13 and 18 cm.) gives consistent results. Briefly stated, this method was as follows:

Measurements were made with each ionization chamber at different distances from the radium, both "in air" and "in water," the surface of the water being 8, 13 and 18 cm. from the radium. Accordingly it is possible to compare the readings in air with the readings in water for any particular depth. The ratios of these readings for the three radium-to-water dis-

tances are in very good agreement. Therefore, having obtained these ratios, it is only necessary to know the readings in air for any particular distance, in order to calculate the corresponding depth doses. The readings in air for the 50 cm. distance can be calculated very simply by applying the inverse square law (starting with a value experimentally determined at a sufficient distance from the radium—more than 10 or 15 cm.). The size of the irradiated field with the pack is not readily controllable on account of the high penetrating power of gamma rays. The value given in the table, 400 sq. cm., is approximately the area effectively irradiated when the pack is used at a distance of 15 cm.

The data in Table II enable us to make some interesting comparisons. Thus, the doses at 10 cm. depth determined with the very thin celluloid chamber (chamber H) are 29.0, 41.2, and 56.7 per cent, for 200 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays, respectively. Under comparable conditions, therefore, 700 kv. roentgen rays and gamma rays deliver consider-

TABLE II

DEPTH DOSES DETERMINED WITH DIFFERENT IONIZATION CHAMBERS

Depth cm.	H	A	I	B	C	F
	Celluloid	Celluloid	Celluloid	Al	Copper	Lead
200 kv. 0.46 mm. Cu+2 mm. celluloid						
0	100	100	100	100	100	100
2	82.6	85.8	87.0	87.5	84.0	81.6
5	59.0	61.1	61.1	65.8	59.0	55.6
7	44.2	47.0	47.3	51.2	44.6	42.3
10	29.0	31.5	32.0	34.9	29.3	27.9
15	13.7	15.1	15.1	17.6	14.8	13.1
20	6.5	7.7	7.7	8.8	7.1	6.2
700 kv. 5 mm. Cu (equiv.)+2 mm. Al+2 mm. celluloid						
0	100	100	100	100	100	100
2	88.5	83.2	86.0	90.5	89.0	84.4
5	70.6	62.8	65.7	73.9	70.9	61.3
7	57.8	49.9	53.5	63.0	60.1	49.0
10	41.2	35.4	38.1	48.3	44.0	33.9
15	23.5	20.2	21.9	29.7	27.1	19.8
20	14.1	12.0	13.2	16.7	16.6	10.8
Gamma rays. 2 mm. Pb (equiv.)+6 mm. bakelite+2 mm. celluloid						
(Measurements made at 8, 13, and 18 cm., and reduced to a 50 cm. distance by calculation)						
0	100	100	100	100	100	100
2	90.2	89.2		86.5	95.7	88.0
5	76.4	74.4	Chamber	72.2	89.0	73.0
7	67.8	65.5	I not avail-	64.6	83.2	64.5
10	56.7	54.0	able at time	54.7	71.7	54.4
15	41.4	38.3	of expts.	41.8	51.0	40.7
20	29.6	28.5		31.9	37.8	29.0

Distance from source to surface of water—50 cm.
Area of irradiated field—400 sq. cm.
Chamber completely submerged for zero position.

ably larger depth doses. The improvement is 42 per cent in favor of 700 kv. roentgen rays, and 96 per cent in favor of gamma rays. At lesser depths this advantage is less marked, while at a depth of 20 cm. it becomes very marked. It will be noted further that a distinct increase in depth dose with increase in (voltage or) penetrating power of the radiation is found with all the ionization chambers. The relative increase, however, is not the same as in the case of the thin celluloid chamber.

The influence of the material of which the chamber is made, and of its wall thickness, on the depth doses, may be studied best by considering each quality of radiation separately. For 200 kv. roentgen rays, the doses at 10 cm. depth increase from 29 to 32 per cent, or about 10 per cent, as the wall thickness of the celluloid chamber increases from about 0.2 to 3.4 mm. With the aluminum chamber of 0.4 mm. wall thickness, a further increase to 34.9 per cent is obtained. The copper and lead chambers, on the other hand, give a depth dose at 10 cm. very close to that obtained with the thin celluloid chamber (29 per cent). Considering the great differences in atomic numbers of the materials used, this close agreement is quite remarkable. It is undoubtedly due to a peculiar combination of circumstances whereby the "wall effect" for the quality of radiation at the surface of the water is about the same as that for the quality of radiation at a 10 cm. depth, even though the actual spectral distribution of the radiation at the two levels is different.

On the basis of this slight variation of depth dose with the material of the chamber (for 200 kv. roentgen rays), one might conclude that almost any small chamber is satisfactory for such measurements. This conclusion, however, is not warranted because the data at hand are not sufficient for such a broad generalization. It will be seen, in fact, that the three celluloid chambers, which are identical except for the wall thickness, give values for the depth doses at 10 cm. of 29 to 32 per cent.

In the case of the 700 kv. roentgen rays the variation of depth dose with respect to the chamber is much more marked and quite irregular. The three celluloid chambers give depth doses at 10 cm. of 41.2, 35.4, and 38.1 per cent, respectively, in the order of increasing wall thickness. The corresponding values obtained with the aluminum, copper, and lead chambers, are respectively 48.3, 44.0, and 33.9 per cent. Similar discrepancies exist among the 10 cm. depth doses for gamma rays obtained with the same ionization chambers. It may be of interest to note that the highest depth dose in the case of 200 kv. roentgen rays was obtained with the aluminum chamber, in the case of 700 kv. roentgen rays with the aluminum chamber also, but in the case of gamma rays the copper chamber gave by far the highest value.

In view of these variations, one is confronted with the problem of deciding which chamber, if any, gives the "correct" values. This cannot be done without defining what we mean by correct values. It will be seen from the results presented in subsequent papers of this symposium that, in general, the quality of radiation exerts a considerable influence on the effects (chemical and biological) produced by radiation. Accordingly the criterion for the choice of the proper depth doses involves in some way a knowledge of the effectiveness of radiation of the wave-length ranges which obtain at the surface and at different depths, so far as the particular change desired is concerned. This question, which is being investigated further, will be discussed in subsequent publications.

At this time, however, we might consider whether any of the chambers used in the experiments permit us to express depth doses in terms of the roentgen. A great deal has been written about "air wall" chambers. Briefly, a small chamber of the type we used is considered to have an air wall if it gives readings which run parallel with the readings of the standard air chamber, over a certain range of wave-lengths. This criterion was applied to our thin celluloid

chamber (chamber H) and the results are given in Figure 6. The wave-length range is indicated by the half-value layer, which extends from 0.1 to 1.5 mm. of copper. The radiation used for each experimental point on the curve was not homogeneous, and the maximum tube voltage was 200 kv. The relation of the small chamber to the standard chamber is expressed in terms of the "effective volume" of the small chamber. This is determined as follows: The intensity of a beam of roentgen rays at a certain point is determined in roentgens per minute by means of the standard air

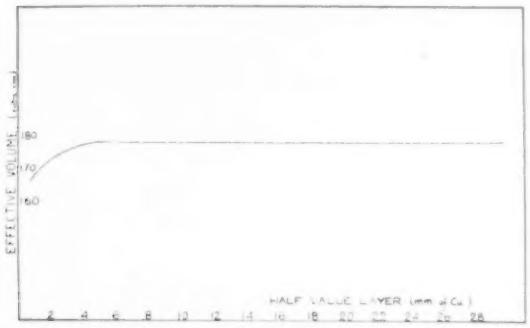


FIG. 6. Comparison of thin celluloid chamber with standard air chamber for different qualities of radiation.

chamber. The small chamber is then placed with its center at the same point of the beam and the ionization current is measured in e.s.u. (electrostatic units). Then

$$\text{Effective volume} = \frac{\text{e.s.u.} \times 60}{\text{r/min.}}$$

If the chamber had "air walls" its effective volume would be the same for all qualities of radiation.

It will be seen from the graph that, while the effective volume of chamber H is not constant, the discrepancy is not marked, considering the large range of wave-lengths over which the comparison was made. It cannot be said with certainty, however, that the long wave-length limit of this range includes the longest wave-length present at different levels of the water phantom at which measurements were made. Since at this limit the discrepancy between the celluloid and the standard chambers becomes considerable, we cannot say definitely that the thin celluloid chamber can be used to express depth doses in roentgens. The very thin celluloid wall of this chamber allows very soft radiation to reach and ionize the air volume. But no one knows definitely at present whether the very soft radiation which is present in an irradiated tissue, due to scattering, etc., and which may be biologically effective, produces the full quota of effect in such an ionization chamber. Certain experiments indicate that the percentage of "back-scattering" is about the same whether it is determined by means of such an ionization chamber or a biological indicator.[5,7] It appears, therefore, that, as a first approximation, our thin celluloid chamber may be used for the measurement of depth doses in roentgens in the case of 200 kv. roentgen rays. The problem, however, deserves further study.

There have been many serious difficulties which have prevented our making measurements of 700 kv. roentgen rays with a standard air chamber under proper conditions. Accordingly the effective volume of the celluloid chamber for this quality of radiation cannot be determined without making certain assumptions. In the expectation of being able to solve this problem later, we shall not express our measurements of 700 kv. roentgen rays in roentgens. Some doubt exists as to the measurement of gamma rays by means of a standard chamber, and the same caution is desirable in this case also. These remarks apply to the measurement of 700 kv. roentgen rays and gamma rays, whether "in air" or with "back-scattering." But if we limit ourselves to the *relative* depth doses, then the thin celluloid chamber is probably just as good for these qualities of radiation as it is for 200 kv. roentgen rays. For this reason the results given in Tables III and IV are based on measurements made with this chamber.

It is well known that the size of the irradiated field makes a considerable difference in the time of exposure required to

TABLE III

INFLUENCE OF SIZE OF FIELD ON DEPTH DOSES

Depth	Irradiated Area in sq. cm.				
cm.	25	50	100	200	400
0	84	91	100	106	110
2	78	87	100	110	118
5	71	84	100	115	128
7	68	82	100	119	134
10	64	80	100	123	142
15	60	77	100	127	154
20	57	74	100	130	162

Voltage—700 kv. peak.
Filter—5 mm. Cu (equiv.)+2 mm. Al+2 mm. celluloid.
Very thin celluloid chamber (H) used.
Chamber completely submerged for zero position.

produce a given effect on the patient's skin, e.g., a certain degree of erythema. Accordingly it is important to know what adjustments in exposure time must be made when the size of the field is varied according to the requirements of the area treated. Correction factors for this purpose were published by us[6] in 1923 relating to 200 kv. roentgen rays. The ones obtained in the course of the present investigation agree quite closely with the old ones. Similar data for 700 kv. roentgen rays are now given in Table III. It may be pointed out, incidentally, that the field area correction factors for 700 kv. roentgen rays do not differ materially from the corresponding ones for 200 kv. roentgen rays. This shows that the *increase* in back-scattering with increase in field area is substantially independent of the wave-length for 200 to 700 kv. roentgen rays. The actual amount of back-scattering, however, is different for the two qualities of radiation, being considerably smaller for 700 kv. roentgen rays than it is for 200 kv. roentgen rays. (The data on this effect will be published in a subsequent paper.)

Table III contains also the correction factors to apply to depth doses determined with a given field when fields of different areas are used. For instance, the intensity of radiation at a 10 cm. depth obtained with the thin celluloid chamber, using 700 kv. roentgen rays under the conditions stated in Table II, is 41.2 per cent for a 400 sq. cm. field. The corresponding depth dose for a 100 sq. cm. field can be calculated by means of the data in Table III. Thus, at the surface the intensity is less with the 100 sq. cm. than with the 400 sq. cm. field in the ratio of 100 to 110. At the 10 cm. depth the corresponding decrease in intensity is in the ratio of 100 to 142. Therefore the percentage depth dose for the 100 sq. cm. field, other conditions remaining the same, is $41.2 \times \frac{110}{142} = 32$ per cent.

TABLE IV

DEPTH DOSES OBTAINABLE WITH RADIUM PACK AT DIFFERENT DISTANCES

Depth cm.	Distance from Source to Surface of Water—cm.					
	6	8	10	12	15	20
0	100	100	100	100	100	100
2	64.8	67.7	71.0	73.3	78.5	83.5
5	36.8	40.5	45.1	49.0	54.8	63.3
7	26.5	29.8	34.1	37.8	43.2	52.3
10	16.3	19.7	23.3	26.3	30.4	39.2
15	8.4	10.8	13.5	15.9	18.7	26.5
20	5.3	6.8	8.7	10.3	13.4	20.7

Very thin celluloid chamber (H) used. Chamber completely submerged for zero position.

The data in Table IV are given in order that the comparison of depth doses obtainable with the three qualities of radiation may be made with the radium pack at the distances used in actual practice. It will be seen that when the radium-skin distance is 6 cm. the depth dose at 10 cm. is only one-

half that obtained with 200 kv. roentgen rays (50 cm. distance). It is only when the radium-skin distance is 15 cm. that the depth doses obtained with the pack attain the values for 200 kv. roentgen rays. In this case the pack has an increasing advantage over 200 kv. roentgen rays for depths greater than 10 cm. With the radium at a 20 cm. distance, the doses at a depth of 10 cm. are comparable to those obtained with 700 kv. roentgen rays, and are even better for the 15 and 20 cm. depths.

In view of the influence which the material and wall thickness of the ionization chamber (as well as other structural and experimental factors) exert on the magnitude of the depth doses obtained with different qualities of roentgen rays, it is hardly necessary to compare in detail the results obtained by us with those obtained by other investigators. Differences are to be expected because different ionization chambers and different experimental setups were used. Also it must be borne in mind that, as shown by Weatherwax and Leddy,[10] the position of the ionization chamber for the surface or "zero depth" reading influences the magnitude of the measured depth dose. As previously stated, the measurements reported here were made with the chamber just submerged when the "surface" reading was obtained. The chamber was then moved, let us say, 10 cm., and the reading obtained in this position was used to calculate the depth dose at 10 cm. Accordingly, in this case the chamber was at a greater depth than it would have been had we started to reckon depth from the half-submerged position of the chamber. With a chamber about 2 cm. in diameter this makes a considerable difference in the depth dose.

There are few data on depth doses obtainable with voltages higher than 200 kv. Our values, however, are much lower than those reported in the *Revue de la Compagnie Générale de Radiologie* (Nov.–Dec.) for a (lower) voltage of 400 kv. The discrepancy is undoubtedly due to the difference in experimental set-up. In fact, the depth doses given in the same report for 200 kv. roentgen rays are also higher than ours in about the same ratio as those for 400 kv. roentgen rays. Furthermore, the 400 kv. depth doses are about the same as would be obtained by using gamma rays under the same conditions. This would allow for no increase in depth dose when the quality of radiation is changed from 400 kv. roentgen rays (5 mm. Cu filter) to that of gamma rays. We feel, therefore, that our depth dose determinations conform more closely to radiotherapeutic conditions than those in the French report.

In view of the fact that the depth doses obtained with 700 kv. roentgen rays are considerably higher than those for 200 kv. roentgen rays, it is evident that 700 kv. roentgen rays are much to be preferred for the treatment of deep-seated tumors. It is true that a comparable increase in depth dose may be obtained by using 200 kv. roentgen rays with a longer target-skin distance than the usual 50 cm. But if this is attempted the filter should be increased also, otherwise the required distance will be too long.

Considering the desirability of using the highest obtainable depth doses in the treatment of certain deep-seated tumors, it is evident that this desideratum can best be met by using the highest voltage available and the longest practical target-skin distance. Roentgen rays produced at 700 kv. (peak) filtered by 5 mm. of copper give depth doses which are considerably lower than those obtainable with gamma rays under comparable conditions. Therefore it is desirable to develop roentgen tubes for still higher voltages.

SUMMARY

1. The distribution of radiation in a water phantom has been investigated, under comparable conditions, for 200 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays.

2. For this purpose, several small spherical ionization chambers were used. The

data given in this paper were obtained with three celluloid chambers of different thicknesses and three metal chambers made respectively of aluminum, copper, and lead.

3. In general, the material of which the ionization chamber is made and its wall thickness influence the depth dose values, due to the variation in the quality of radiation within the depth of water.

4. A small ionization chamber of the type required for depth dose measurements must have no wall effect over the range of wave-lengths present in the water phantom, in order that depth doses may be expressed in terms of the roentgen. The very thin celluloid chamber meets this requirement more closely than any other used in our experiments. Further investigation is necessary, however, before we can say definitely that such a chamber is satisfactory for this purpose.

5. It has been impossible so far to make the proper comparison between a small ionization chamber and a standard air chamber in the case of 700 kv. roentgen rays and gamma rays. For this reason it is preferable at present not to assume that a small ionization chamber can be calibrated to read correctly in terms of the roentgen from 200 kv. roentgen rays to gamma rays.

6. The relative depth doses at 10 cm. depth obtained under comparable conditions with 200 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays, are respectively 29.0, 41.2, and 56.7 per cent. Accordingly from this point of view, 700 kv. roentgen rays are considerably better than 200 kv. roentgen rays, but not so good as gamma rays.

7. Owing to the fact that the high cost of radium precludes its application at distances comparable to the target-skin distances generally employed in roentgen therapy, the advantage of the greater penetration of gamma rays is not fully realized in practice. When a radium pack is applied at a distance of 15 cm., the dose at a 10 cm. depth is approximately the same as that delivered by 200 kv. roentgen rays, filtered by about 0.5 mm. of copper, using a target-skin distance of 50 cm. and a field of 400 sq. cm.

8. Depth doses for the radium pack have been determined for distances in the practical range of 6 to 20 cm.

9. The influence of the size of the irradiated field on depth doses has been investigated both with 200 and 700 kv. roentgen rays. A table of correction factors for 700 kv. roentgen rays is given.*

The authors wish to express their indebtedness to Mr. S. Suozzi and Mr. R. C. Woods for the valuable assistance rendered during the course of the experiments, and to Mr A. Schreiner and Mr. K. Bender, of our machine shop, for the construction of the apparatus.

* For discussion see page 362

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THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

II. COMPARISON BASED ON EFFECTS ON IODIDES, EDER'S SOLUTION, AND PHOTOGRAPHIC FILM*

By H. Q. WOODARD, Ph.D., E. H. QUIMBY, M.A., *and* H. R. DOWNES, Ph.D.
Chemical and Biophysical Laboratories, Memorial Hospital
NEW YORK CITY

INTRODUCTION

THE USE of a chemical standard for determining quantity of roentgen radiation has been advocated from time to time, various chemical reactions having been proposed for the purpose. A number of different reactions can be brought about by the action of ionizing radiations, and theoretically any of these could be used as a standard. As a matter of fact, most of them are open to serious objections for this purpose. Many of them require such large amounts of radiation to bring about measurable changes as to be impractical. The photographic reactions, on the other hand, require such small amounts that they cannot readily be used for radiations of any great intensity. They are, nevertheless, very useful in certain cases. Of the reactions falling in a convenient range as regards quantity of radiation necessary, some require very complicated technique in their investigation—a drawback for a standardization reaction. Others occur in compounds which are somewhat unstable under control conditions, so that a relatively large part of the reaction is spontaneous. There are, however, two chemical reactions which have been studied at Memorial Hospital and found quite satisfactory for purposes of standardization. One of these, the precipitation of mercurous chloride from Eder's solution, has been described elsewhere.[1] The other, the liberation of iodine from certain iodides in acid solution, will be described in full in this paper.

The present report is a part of a comprehensive comparison of three different types of radiation from many angles. The radiations used were: (1) roentgen rays generated at 165 or 200 kv. peak, with a filter of 1.65 mm. Cu, 0.5 mm. Al, and 3.0 mm. celluloid; (2) roentgen rays of 700 kv. peak, with a filter equivalent to 5 mm. Cu, 2 mm. Al, and 3.5 mm. celluloid; (3) gamma rays, with a primary filter equivalent to 2 mm. Pb, and a secondary filter of 6 mm. bakelite, and 1.0 mm. celluloid. The output of the 165 kv. x-ray machine was determined in roentgens by means of a standard air ionization chamber. This method, however, has not been fully developed to permit its application to roentgen rays at considerably higher voltages, or to gamma rays. Therefore the measurement of these types of radiation has been made by means of all the reactions included in this study. For example, if the 165 kv. roentgen rays precipitated 0.5 mg. of mercury as mercurous chloride from 5 c.c. of Eder's solution in half an hour with an exposure of 200 roentgens, it could be stated that the deposition of 1 mg. of mercury would correspond to 400 r. If now in an equal time, the 700 kv. radiation precipitated 0.4 mg. of mercury, it could be said to have delivered $400 \times \frac{4}{10} = 160$ r. Its output would then have been $\frac{160 \text{ r}}{30} = 5.3$ r per minute.

If it is true that the production of a chemical change depends only on the quantity of radiation used and not on the quality, then the values found for the outputs of the three sources should be the

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932

same by all chemical methods of measurement. If, on the other hand, the factor of quality enters, these values may be different for every reaction used.

In this paper will be presented the results of comparisons based on the two reactions already mentioned, and on the darkening of photographic films, with and without the addition of intensifying screens.

IODIDES

Method. Preliminary experiments showed that the concentration of iodine liberated by roentgen radiation from an acid solution of potassium iodide was approximately proportional to time of irradiation at a given roentgen-ray setting. The concentration of iodine liberated was too low for accurate determination by the usual method of titration against thiosulphate, and most colorimetric methods for determining traces of iodine involve elaborate manipulations.[2,3] It was therefore necessary to develop a rapid and accurate method for determining the iodine content. The following method was found to be satisfactory:

A standard solution of iodine was made up by placing about 0.125 gm. resublimed iodine and about 1.0 gm. potassium iodide in a 500 c.c. volumetric flask with 10 c.c. of water, shaking until the iodine was dissolved, and making up to 500 c.c. The solution was then standardized by titrating against 0.005 N sodium thiosulphate, with starch as an indicator. It was necessary to standardize the solution every two days for the first two weeks after preparation, as the concentration was found to change somewhat during this time. After the first two weeks the concentration remained unchanged in the neighborhood of 0.002 N for three months, and was checked only once a week. The solution was kept in the dark.

Stock solutions of potassium or lithium iodide of double the concentration of the mixture to be irradiated were made up in volumetric flasks. These solutions would keep for a week in the dark without appreciable spontaneous liberation of iodine. It is important that the solutions should be made up in volumetric flasks rather than by the addition of a measured volume of water to the solid salt, as considerable change in volume occurs on solution. Temperature change also occurs so that the solutions should be allowed to come to room temperature before the final few drops of water are added.

Two per cent starch solution was made up by making a paste of 2 gm. of soluble starch in 10 c.c. of cold water, adding this slowly to 90 c.c. of boiling water, and boiling for five minutes. The solution was slightly opalescent without visible flocculation, and would keep for a week.

Stock solutions of N/1 H_2SO_4 and N/1 HNO_3 were kept on hand.

Immediately before the beginning of irradiation the above solutions were mixed and diluted to the required concentration. The mixture most frequently employed contained 10 per cent KI, 0.05 N H_2SO_4, and 0.5 per cent starch. As explained below, lithium iodide was also investigated, as well as solutions containing different concentrations of KI and of H_2SO_4, and a solution containing 10 per cent KI and 0.05 N HNO_3. All of these acid iodide solutions underwent spontaneous decomposition of iodide with liberation of iodine. This decomposition was much more rapid in the light than in the dark. Hence they were placed in a dark box as soon as prepared, kept there until they were irradiated, and were shielded from the light of the roentgen tube during irradiation. Even with these precautions some spontaneous liberation of iodine took place. The amount of this spontaneous decomposition was determined by reserving a portion of each solution as a control. The control was kept in the same box with the experimental solution and its iodine concentration was read at the end of the experiment and subtracted from the experimental readings.

At the same time that the experimental solution was prepared, a standard was made up by diluting the stock iodine standard to one-tenth its concentration with iodide

and starch, so that the final concentration of iodide and starch in the standard was the same as in the experimental solution. As an example, if the experimental solution contained 10 per cent KI, 0.05 N H_2SO_4, and 0.5 per cent starch, the standard was made by placing 2.5 c.c. of 0.0021 N iodine, 12.5 c.c. of 20 per cent KI and 6.25 c.c. 2 per cent starch in a 25 c.c. volumetric flask and making up to 25 c.c., the final concentration of iodine being 0.00021 N. As no acid was used in the preparation of the standard, this would keep for twelve hours without appreciable change in concentration.

After irradiation of the experimental solutions, the concentration of iodine liberated was read by comparison with the standard in the colorimeter.

It was found that the concentration of starch employed (0.5 per cent) was sufficient to combine with all the iodine liberated by the largest doses of radiation studied, so that the depth of color observed was directly proportional to the iodine concentration.* The reason for adding the starch before irradiation of the solutions was not only to avoid the dilution errors which would have occurred had the starch been added to small portions of the iodide solution after irradiation, but also to stabilize the iodine. Dilute solutions of iodine are unstable when exposed to the air, but the starch iodine compound was found to be fairly stable. There was no evidence that the radiation produced any change in the starch itself which caused secondary reactions with the iodine.

It is necessary that the concentration of iodide in the standard should be very nearly the same as that in the unknown. This is because the color of the starch-iodine solution containing a constant concentration of starch and iodine varies from a deep blue when only traces of iodide are present to a pale red-brown in 25 per cent KI solution. Since at the maximum roentgen exposures used, only about 1/1000 of the iodide originally present was decomposed by irradiation, the concentration of iodide in the experimental solutions was not sufficiently changed to affect the color of the starch-iodine compound.

All experiments with the 165–200 kv. and the 700 kv. roentgen rays were done at least in duplicate. The dishes or cells containing the solutions for duplicate determinations were placed diagonally opposite each other in the roentgen field, so that any possible asymmetry in the field would not affect the averages of the results. Each experiment usually consisted of a series of five to seven exposures in duplicate of portions of the same solution irradiated for different times or with different filters. As the time required to read such a series of solutions in the colorimeter was from thirty to forty-five minutes, appreciable spontaneous liberation of iodine could take place between the time of the first and the last readings. For this reason the different members of a series were always read in definite order. Suppose the different samples of solution in the series to be A_1 and A_2, B_1 and B_2,—F_1 and F_2, solutions of the same letter being duplicates. The readings were made in the following order—Control, A_1, B_1, C_1, D_1, E_1, F_1, F_2, E_2, D_2, C_2, B_2, A_2, Control. In this way, the average time of reading all the solutions and the controls was the same. Where only two or three solutions had to be read, this procedure was not necessary. The maximum time elapsing in any experiment between the preparation of the solution and the final analysis was four hours.

Part of the solutions were irradiated in glass crystallizing dishes 46–49 mm. in diameter, covered with a sheet of celluloid 0.9 mm. thick. The remainder of the solutions were irradiated in disk-like celluloid cells 60 mm. in internal diameter, 0.9 mm. wall thickness, 4.5–5.0 mm. thickness between walls, capacity about 15 c.c. They were filled through an aperture about 15

* Since the paper was submitted for publication it has been found that this proportionality does not hold over as wide a range of concentration as that for which it has been employed. The figures given herewith are therefore in error by amounts up to about 5 per cent of the total concentrations reported. Further work on the method is in progress.

mm. long in the rim. When they were used in a horizontal position the apertures were closed by wide rubber bands which passed entirely around the rim of the cell.

Experimental. A satisfactory chemical method of measuring radiation should fulfill certain requirements.

A. It should be effective over the range of therapeutic dosage.

B. The effect observed should be proportional to time of irradiation, other conditions being constant, and there should be no zero error.

C. It should be reproducible from day to day.

Let us see how well the iodide method fulfills these requirements.

A. The effective range. For the x-ray setting 165 kv., 19¼ ma., 50 cm. target distance, 1.65 mm. Cu, 0.5 mm. Al, 3.0 mm. celluloid filter, a solution containing 10 per cent KI, 0.05 N H_2SO_4, 0.5 per cent starch will give a satisfactory measure of quantities of radiation from about 200 to 2000 roentgens. For the same setting a solution containing 25 per cent KI, 0.05 N H_2SO_4, 0.5 per cent starch may be used over a range of 50 to 600 r. The therapeutic range is well within this. The method is also effective over the therapeutic range for the radium element pack and the 700 kv. roentgen machine.

B. Time of exposure. If the effect observed is proportional to time of exposure to radiation, other conditions being constant, then when the concentration of iodine liberated from a given solution is plotted against time of irradiation, the resulting curve should be a straight line and the line should pass through the origin. Such curves were plotted for four different solutions for three types of irradiation. The solutions were:

10 per cent KI, 0.05 N H_2SO_4, 5 per cent starch.
10 per cent KI, 0.05 N HNO_3, 5 per cent starch.
10 per cent LiI, 0.05 N H_2SO_4, 5 per cent starch.
25 per cent KI, 0.05 N H_2SO_4, 5 per cent starch.

The types of radiation were:

165 kv.; 19¼ ma.; 1.65 mm. Cu, 0.5 mm. Al, 3.5 mm. celluloid; 50 cm. from target to center of solution.

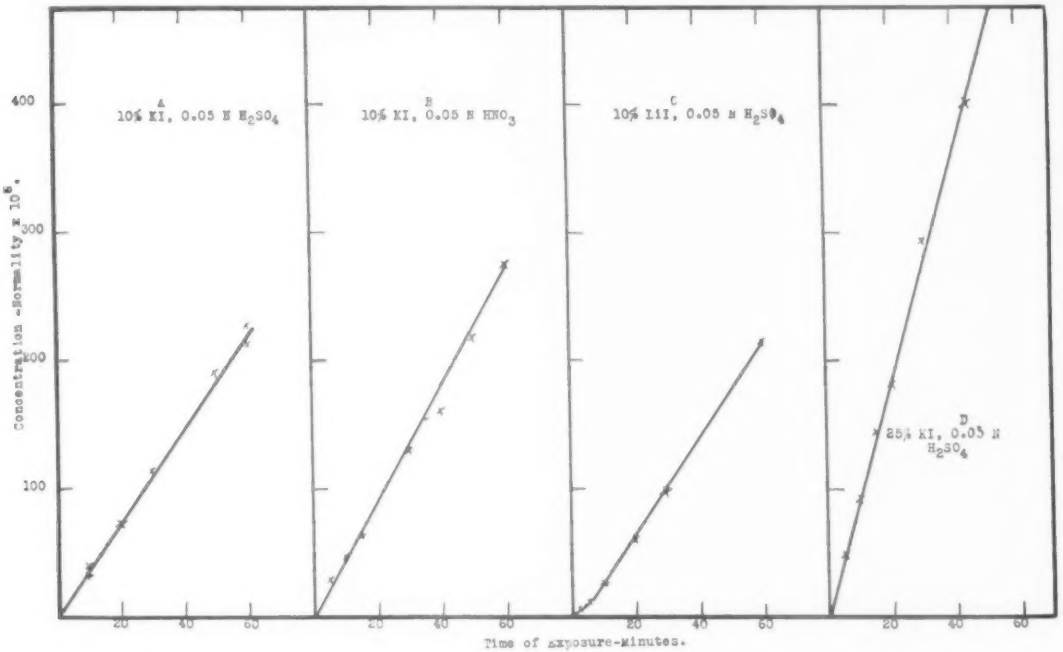

Fig. 1. Effect of time of irradiation with 165 kv. roentgen rays on the concentration of iodine liberated from different iodide solutions.

700 kv.; $2\frac{3}{4}$ ma.; 5.0 mm. Cu, 2.0 mm. Al, 3.5 mm. celluloid; 48.5 cm. from target to center of solution.

Radium element pack; primary filter equivalent to 2 mm. Pb; secondary filter of 6 mm. bakelite; 1.0 mm. celluloid; 7.0 cm. from radium to center of solution.

Figures 1, 2 and 3 show the results of this work. Each curve for roentgen radiation represents a single experiment, so that long period variation in the output of the machine is avoided. Each curve for the radium pack represents several experiments. Points on the roentgen curves are averages of two determinations; points on the radium curve are for single determinations. It is seen that, within the limits of experimental error, all the curves are straight lines. As was explained above, there is a large zero correction in all these experiments, owing to the spontaneous liberation of iodine in the acid iodide solutions. The correction amounts to from 5 to 75 per cent* of the total concentration of iodine observed, according to the solution used, the concentration of iodine liberated by irradiation, and the time elapsing between the preparation of the solution and the final analysis. For all experiments in glass containers the control readings for a given time are very constant. There is, however, considerable variation in the controls in the celluloid cells, and the spontaneous liberation of iodine in celluloid is usually much more rapid than in glass. The behavior of lithium iodide in celluloid is especially variable, so that considerable error is probably introduced into the final figures for this solution. However, the curves all pass very nearly through the origin after zero correction has been applied. It appears then that iodine is liberated from all of the four solutions in concentrations proportional to the time of irradiation, other conditions being constant.

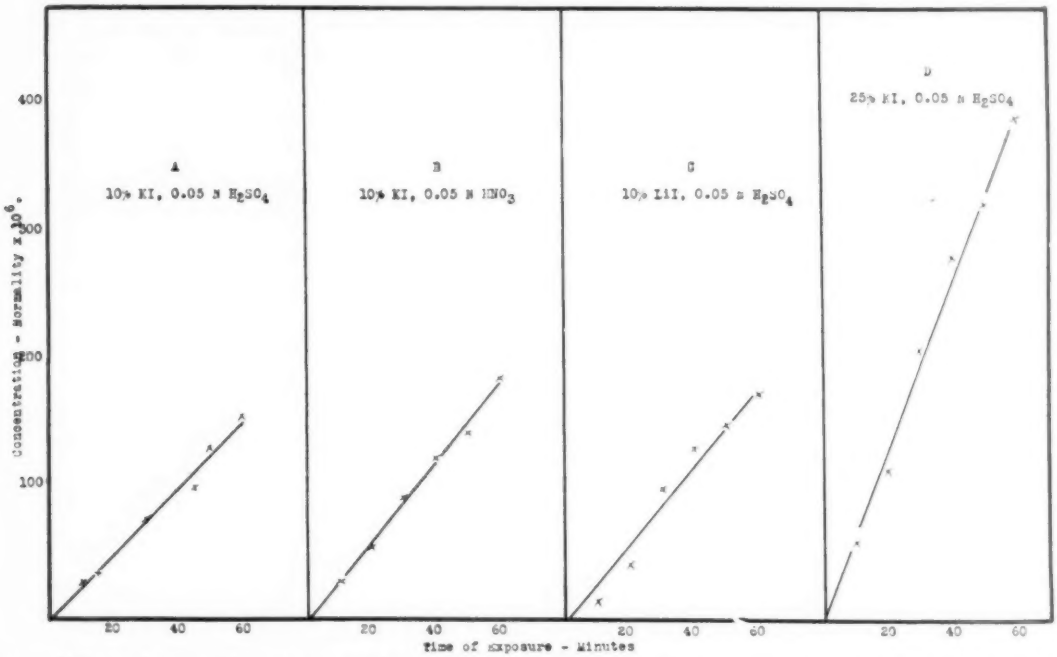

FIG. 2. Effect of time of irradiation with 700 kv. roentgen rays on the concentration of iodine liberated from different iodide solutions.

C. Reproducibility. For a solution containing 10 per cent KI, 0.05 N H_2SO_4, 0.5 per cent starch, the analytical error, as shown by differences between different portions of the same solution irradiated at

* Large percentage corrections were necessary only in reading the effect of very short exposures to gamma radiation.

the same time, amounts to differences in concentration of ± 0.000005 N. This means that the actual error in determining quantities of radiation ranges from 10 per cent to 1 per cent according to the concentration of iodine measured.

The reproducibility from day to day with this solution was investigated by making a series of measurements in duplicate of quantities of radiation amounting to about 1000 r delivered by a roentgen machine, the output of which could be held very constant by means of an ionization chamber connected to a galvanometer and calibrated by means of a standard cell. The variation from day to day was found to be ± 0.000004 N. This is less than the analytical error, and amounts to an error of ± 2 per cent in the measurement of the radiation. The method may therefore be used to measure quantities of radiation in the neighborhood of 1000 r with a precision of ± 2 per cent.

Measurements with the other solutions investigated, if made in glass containers, can be made with a precision only slightly less than that obtainable with solutions containing 10 per cent KI in 0.05 N H_2SO_4. Measurements made in celluloid containers show a much larger variation than those made in glass, however. All determinations made for the purpose of comparing gamma rays, 700 kv., and 165 kv. roentgen rays, were made in celluloid containers, because the 700 kv. roentgen beam is horizontal, and irradiation had to be done through the side of the container. For this reason, and because the concentration of iodine liberated by exposure of iodide solutions to gamma rays was very low, the measurements of gamma rays were accurate to only ± 10 per cent, and measurements of 700 kv. and 165 kv. roentgen rays were accurate to ± 5 per cent.

Before comparing the effects of different qualities of radiation it is desirable to study the effect of radiation of a given quality on solutions of different concentrations, acidities and depths.

Preliminary work on the effect of concentration of H_2SO_4 on the concentration of iodine liberated from 10 per cent KI by roentgen radiation at 200 kv., 0.5 mm. Cu filter, shows that the concentration of iodine liberated increases slowly with increasing concentration of acid. This is in accord with the findings of Kailan.[4] Solutions containing H_2SO_4 in concentrations

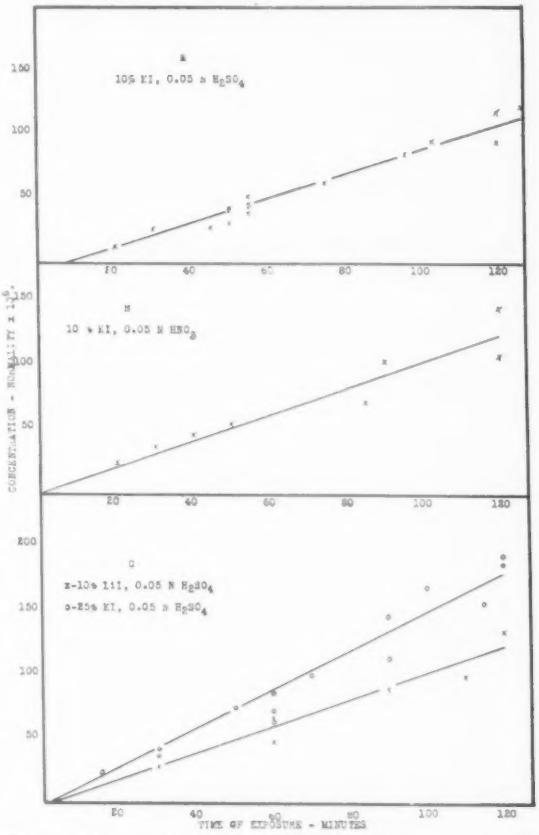

FIG. 3. Effect of time of irradiation with gamma rays on the concentration of iodine liberated from different iodide solutions.

from 0.001 N to 0.10 N were examined, and it was found that a hundred fold increase in acid concentration resulted in an increase of only about 50 per cent in the concentration of iodine liberated. Since neutral solutions of KI are almost unaffected by roentgen rays, and since solutions containing only 0.001 N H_2SO_4 are conspicuously radiosensitive, it is planned to investigate solutions of acidities ranging from zero to 0.001 N.

The negative ion of the acid as well as the hydrogen ion influences the liberation of iodine from acid KI solutions by radiation. This is shown by the fact that about 50 per cent more iodine is liberated from a 10 per cent KI solution by a given dose of 165 kv. roentgen radiation when the solution contains 0.05 N HNO_3 than when it

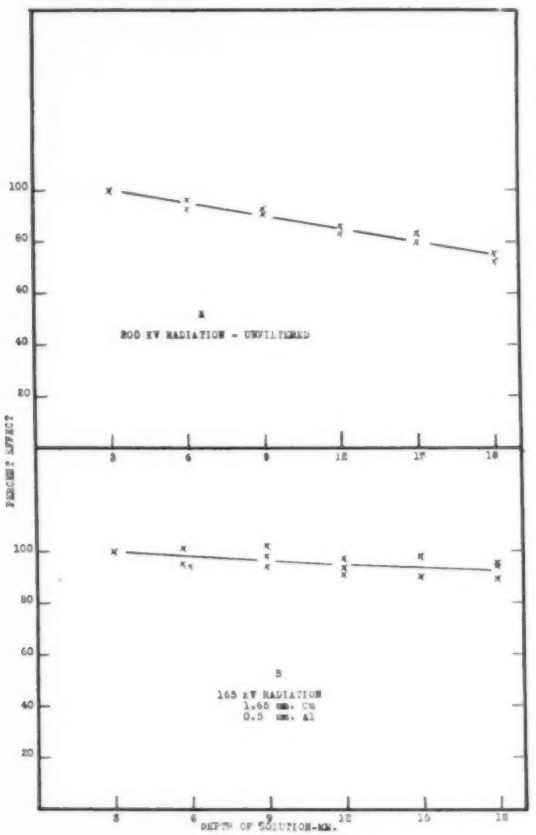

FIG. 4. Effect of depth of solution on the concentration of iodine liberated from a solution containing 10 per cent KI, 0.05 N H_2SO_4 when irradiated with filtered and unfiltered roentgen rays.

contains 0.05 N H_2SO_4. As we shall see later, the absorption curves for the two solutions also differ. It is planned to investigate the effect of a number of different acids on the radiosensitivity of KI.

The concentration of iodine liberated from solutions containing different concentrations of KI and the same concentration (0.05 N) of H_2SO_4 by irradiation at 200 kv., 30 ma., 0.5 mm. Cu filter, for equal periods of time is almost, but not quite, proportional to the initial concentration of KI. It is planned to make further comparisons of different iodides, and of different concentrations of the same iodide in order to throw more light on factors influencing the exact concentrations of iodine liberated by given doses of radiation. It is evident from data already at hand that the concentration of iodine liberated from KI solutions of different concentrations is not greatly influenced by the effective atomic number of the solutions.

It appears also that the ratio of the concentration of iodine liberated from 10 per cent KI and 25 per cent KI by 200 kv. roentgen rays and by gamma rays is not the same, the ratios found from experiments in glass containers being 1:2.70 and 1:2.28 respectively. Further work is being done on this problem.

If, when a solution is irradiated, a considerable part of the radiation is absorbed, the lower layers of the solution will receive less radiation than the upper. In such a case, the deeper the solution irradiated, the lower will be the average concentration of iodine in the solution as a whole. If, however, the radiation is of a penetrating type, only a small portion of it will be absorbed in the upper layers of the solution and the concentration of iodine will be almost independent of the depth. Figure 4 shows the effect of depth of solution on the concentration of iodine liberated from 10 per cent KI by two types of radiation. For nearly unfiltered radiation the concentration of iodine decreases with increasing depth; for highly filtered radiation the concentration is nearly independent of depth. Absorption curves also show differences for different depths of a solution, as is shown in Figure 5. The data shown in the curves in this figure are calculated as percentage of the effect observed with 2.5 mm. copper filter in order to show more clearly the differences between the curves in the region of lightly filtered radiation. The relations of the curves for solutions of different depths to each other and to the ionization curve

are very complex. For these reasons comparisons between effects with different solutions, different types of radiation, etc., were made on solutions of the same depth unless otherwise stated. Two depth ranges were used, 2.6–2.8 mm., or the depth of 5 c.c. of solution in the glass dishes, and 4.5–5.0 mm., or the internal thickness of the celluloid cells and the depth of 9 c.c. of solution in the glass dishes.

measurements of the 165 kv. roentgen and gamma rays made in celluloid were also found to differ somewhat from those made in glass. The uncertainties introduced by the use of celluloid are not sufficiently large to affect the comparisons seriously, however.

The calculations for Table 1 were made as follows: The output in r/min. of the 165 kv. machine was measured with an air

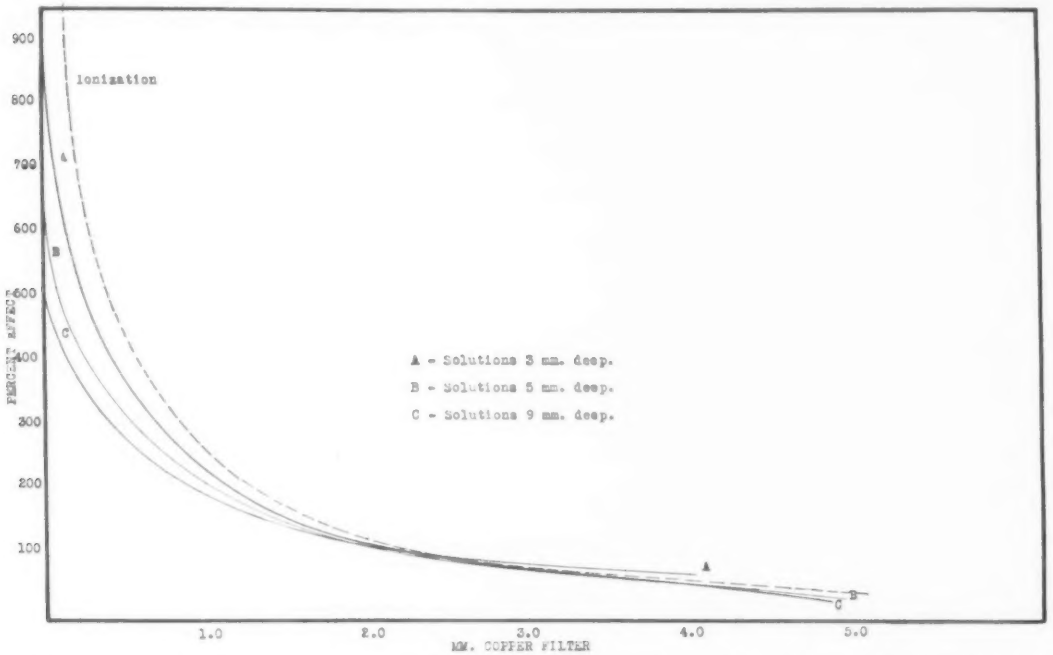

Fig. 5. Absorption curves for solutions of different depths. Ten per cent KI in 0.05 N H_2SO_4 irradiated with 200 kv. roentgen rays.

The outputs of the 700 kv. roentgen machine and of the radium element pack have been measured using four different iodide solutions and taking as standard the concentration of iodine liberated from each solution by radiation at 165 kv. with 1.65 mm. Cu and 0.5 mm. Al filter. Data for this comparison are given in Table 1. It was necessary to use celluloid containers for all these comparisons owing to the fact that the beam of radiation from the 700 kv. roentgen machine was horizontal and the exposure had to be made through the side of the container. The experimental error was therefore larger than for determinations made in glass. The average values for

ionization chamber, at the experimental distance and with the experimental filters. This output is recorded in column 2 of the table. The concentration of iodine liberated by the 165 kv. radiation under experimental conditions was determined, and also by radiation at 700 kv. and by gamma radiation. These concentrations, all calculated to the values for 60-minute exposures are recorded in column 6. From the known output of the 165 kv. machine, and the concentration of iodine liberated, the number of roentgens equivalent to a definite concentration of iodine was calculated and recorded in column 7. Now, assuming that a given number of roentgens will al-

ways liberate the same concentration of iodine from a given solution, regardless of the quality of the radiation, it is possible to calculate for each solution, from the data in column 7, the number of roentgens equivalent to the concentration of iodine set free by the 700 kv. and gamma radiations. These figures are recorded in column 8. Since these values are all based on an exposure time of 60 minutes, the apparent intensity of radiation at the distances at which the chemicals were irradiated can be calculated by dividing the values of column 8 by 60. The results, expressed in roentgens per minute, are given in column 9. For purposes of comparison with the results of other experiments presented in this symposium, the figures of column 9 have been reduced to standard distances of 50 cm. for roentgen rays and 6 cm. for the radium pack. They are given in column 10.

It is evident from the table that measurements of the output of the 700 kv. roentgen machine by means of iodide solutions give different values for each solution used, the percentage difference between the outputs of gamma radiation as measured by the different iodide solutions being very much larger than for 700 kv. roentgen rays. These differences have been confirmed by experiments in glass. They are therefore not due to errors from action of the solutions on the celluloid cells, but indicate a real differential action of radiation on the different solutions.

Table I

COMPARISON BASED ON EFFECT ON IODIDES

All concentrations are calculated to the values for 60-minute exposures

Type Radiation	r/min. Measured	Total r Measured	Solution	No. Determinations	Average Concentration Iodine Liberated Normality $\times 10^6$	No. of r Equivalent to 0.000100 N Iodine	Total r Calculated	r/min. at Experimental Distance	r/min. at Standard Distances
165 kv.	8.75	525	10% KI	16	179 ± 10	293		8.75	8.75
700 kv.			0.05 N	15	146 ± 15		428	7.10	6.68
Gamma			H_2SO_4	14	50 ± 5		147	2.45	3.24
165 kv.	8.75	525	10% KI	10	257 ± 8	204		8.75	8.75
700 kv.			0.05 N	9	186 ± 15		380	6.30	5.93
Gamma			HNO_3	6	56 ± 10		114	1.90	2.51
165 kv.	8.75	525	10% LiI	8	204 ± 6	257		8.75	8.75
700 kv.			0.05 N	9	200 ± 24		515	8.60	8.09
Gamma			H_2SO_4	5	59 ± 6		152	2.53	3.34
165 kv.	8.75	525	25% KI	10	449 ± 28	117		8.75	8.75
700 kv.			0.05 N	11	383 ± 30		448	7.50	7.06
Gamma			H_2SO_4	11	85 ± 7		99.4	1.66	2.19

EDER'S SOLUTION

The effect of roentgen rays on Eder's solution has been described in detail in a previous publication.[1] For the present comparison, the method of irradiation was in general the same as that used with the iodine solutions. Instead of 165 kv. roentgen rays, with 1.65 mm. Cu and 0.5 mm. Al filter, 200 kv. were used, with 0.5 mm. Cu and 3 mm. Al. It was shown, however, that within this range the mercury values agreed closely with the ionization measurements. It is therefore equally satisfactory to use either quality of radiation in this

case. The comparison is presented in Table II for groups of experiments made during a short period of time, the same solutions having been used throughout. Each roentgen-ray value in the table is the average of four consecutive or simultaneous experiments which differed little among themselves; each radium value the average of two. In column I are given the times of exposure, in column II the outputs in roentgens per minute, as determined by ionization measurements. The total r as measured (column III) has been recorded only for 200 kv. roentgen rays. In column IV are given the milligrams of mercury precipitated per 5 c.c. of Eder's solution. From the values in columns III and IV for 200 kv. roentgen rays may be determined the number of roentgens of this radiation necessary to precipitate 1 mg. of mercury from 5 c.c. of solution. Now, assuming that for the other qualities of radiation, the same amount of mercury will be precipitated by the same number of roentgens, it is possible to calculate the total output and the r/min. for the other sources. This is done, and the values recorded in columns VI and VII, for the distances actually used in the experiments. The last column gives these outputs reduced to the standard distances of 50 cm. for the 700 kv. roentgen rays and 6 cm. for the radium pack.

TABLE II

COMPARISON BASED ON EFFECT ON EDER'S SOLUTION

I	II	III	IV	V	VI	VII	VIII
Time of Exposure min.	r/min. Measured (ion.)	Total r Measured	Mg./Hg per 5 c.c. Solution*	No. of r Equiv. to 1 mg. Hg/5 c.c. Solution	Total r Calculated	r/min. at Experimental Distance	r/min. Standard Distance
			200 kv.				
5	66	330	1.03	320			
5	66	330	0.98	337			
5	66	330	0.99	334			
Av. 5	66	330	1.00	330			
			700 kv.—48.5 cm.				50 cm.
20			0.79		260	13.0	12.1
20			0.79		260	13.0	12.1
20			0.83		274	13.7	12.7
Av. 20			0.80		265	13.2	12.3
			Radium Pack—7.0 cm.				6 cm.
60			0.645		212	3.5	4.5
60			0.570		188	3.1	4.0
60			0.635		209	3.5	4.5
60			0.635		209	3.5	4.5
Av. 60			0.621		205	3.4	4.4

* Each value given for roentgen rays in the table is the average of four experiments made in immediate succession or simultaneously; for the radium pack, it is the average of two.

PHOTOGRAPHIC COMPARISONS

As has been mentioned earlier in this paper, photographic reactions are brought about by the use of exceedingly small quantities of radiation. The three types of radiation compared in this work all have considerable intensities, and, in order to produce the chemical effects already discussed, must operate for a period of at least several minutes. Such an amount of radiant energy would produce complete blackening of films. In order, therefore, to use the same types of radiation, it is necessary either to use much shorter times of exposure, or much longer distances from the source of energy, or both. When intensifying screens are used, these difficulties of course become more pronounced. For the purposes of this experiment it was found necessary to use the radium pack at 15 and 45 cm., the 700 kv. roentgen tube at 145 and 400 cm., and the 185 kv. roentgen tube at 200 and 400 cm. With the shorter distances, data could be obtained without intensifying screens; when these were used, the longer distances were necessary. Under these conditions, exposure times ranged between 20 and 120 seconds.

The precautions necessary when the photographic densities of films are to be compared have been discussed in a previous paper.[5] It may be mentioned that films cannot be compared unless they have been developed under *identical* conditions. Practically this means that they must have been developed simultaneously in the same solutions. After the films have been measured in a densitometer, comparisons may be made only along the parts of the density curves which are practically linear, and preferably within a range of densities from 0.3 to 0.7.

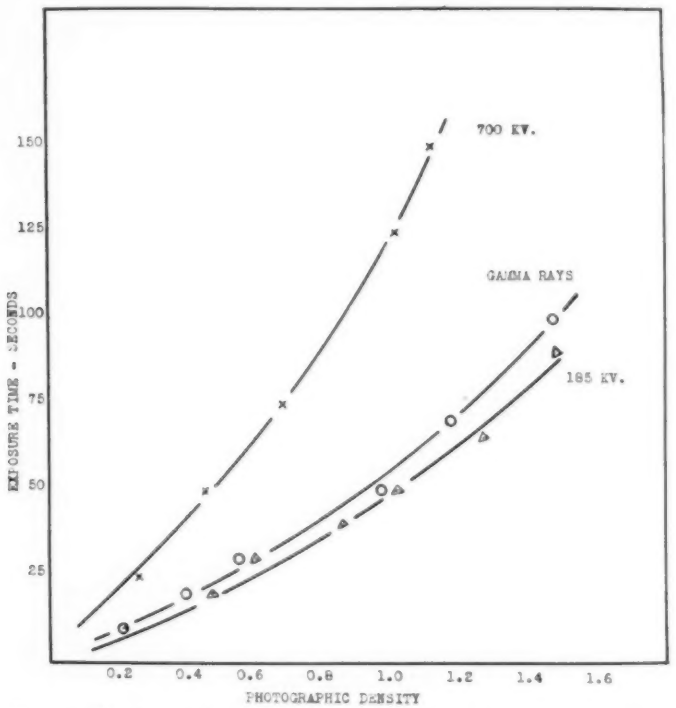

FIG. 6. Variation in photographic density of unscreened films with time of exposure to three types of radiation.

The experimental procedure was as follows: In order to insure the greatest possible homogeneity in the test material, for each experiment a large roentgen film was cut into pieces about 8 × 2 cm. Each piece was wrapped in three thicknesses of black

paper—the wrappers being cut to a standard size—and sealed. For the work with screens, a large screen, of a standard make, was cut into pieces of the same size as the films; these pieces were matched in pairs, and the same two always used together. In making a direct comparison of the three types of radiation, without screens, about 75 pieces of film were used. All exposures were in triplicate, and for each type of radiation from six to eight exposure times were used. The films were then divided into three groups, each group containing one film from each exposure. All films of a group were developed simultaneously in the regular developing tanks of the roentgenographic department, dental film holders being used. After drying, the films in each group were measured with a photoelectric densitometer and curves plotted, of the type shown in Figure 6, showing the variation in film density with exposure time for each type of radiation. From such a set of curves can be found directly the times of exposure necessary to produce equal blackening on the films. Then, as measured by the films, the amounts of radiation delivered by the three sources in a set of times corresponding to a specified density are equal. From this information, if the output of one source is known, that of the others can be calculated, as will be explained later in the paper.

It was not practicable to follow an analogous procedure with the intensifying screens. Even with the greatest distances possible with the roentgen machines, the exposures had to be very short, so that it was difficult to time them accurately. Also there was noticeable variation among films exposed simultaneously, due to irregularities in the screens themselves, although a selection of 50 pairs giving the best results had been made from a considerably larger number. Therefore it was desirable to have a great many more exposures for any given set of radiation specifications. For this reason it seemed better, for each type of radiation, to compare directly the action on the films with and without screens. Then, since comparative data for the three types were available for the unscreened

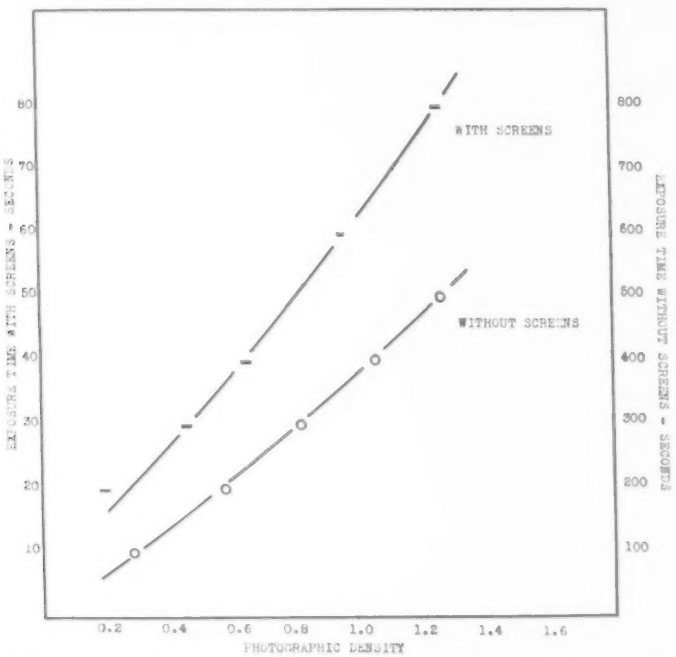

Fig. 7. Variation in photographic density of screened and unscreened films with time of exposure to three types of radiation.

films, corresponding results could be calculated for those with screens. In these experiments, for each type of radiation, four unscreened and nine screened pieces of film were used for each exposure time. They were then divided into two groups, each containing two sets of unscreened film and four or five sets of screened ones, which were developed and measured as described above. From these data, curves such as those in Figure 7 were constructed, showing the variation in photographic density with exposure time, for the films with and without screens. On the curve for the screened films, the horizontal lines indicate the variation in density among the films of the set for a given exposure. From such a pair of curves can be found, for the type of

TABLE III

COMPARISON BASED ON EFFECT ON PHOTOGRAPHIC FILMS WITHOUT SCREENS

I	II	III	IV	V	VI	VII	VIII
		185 kv. x-rays 204 cm.–0.27 r/min.		700 kv. x-rays 145 cm.		Radium pack 15 cm.	
Experiment	Density	Exposure Time (Sec.)	Total r	Exposure Time (Sec.)	r/min.	Exposure Time (Sec.)	r/min.
I	0.4	30	0.135	67	0.121	35	0.231
	0.5	39	0.175	90	0.117	46	0.228
	0.6	48	0.216	117	0.111	58	0.224
	0.7	57	0.256	150	0.102	69	0.223
II	0.4	40	0.180	90	0.120	46	0.235
	0.5	52	0.234	124	0.113	58	0.242
	0.6	64	0.288			71	0.244
	0.7	75	0.337			84	0.241
III	0.4	20	0.090	39	0.138	20	0.270
	0.5	23	0.103	49	0.126	25	0.246
	0.6	26	0.117	61	0.115	29	0.242
	0.7	30	0.135	72	0.112	35	0.231
IV	0.4	23	0.103	56	0.110	28	0.272
	0.5	29	0.132	70	0.113	35	0.226
	0.6	36	0.162	84	0.116	42	0.231
	0.7	43	0.193	101	0.115	49	0.236
V	0.4						
	0.5	20	0.090	54	0.101	25	0.216
	0.6	25	0.112	65	0.103	30	0.224
	0.7	31	0.136	78	0.104	36	0.226
VI	0.4	26	0.117	63	0.112	32	0.219
	0.5	34	0.153	80	0.115	40	0.229
	0.6	42	0.188	98	0.115	49	0.230
	0.7	50	0.225	116	0.117	57	0.237
Av.					0.114		0.234
Av. Reduced to Standard Distances				(at 50 cm.–1.0 r/min.)		(at 6 cm.–1.18 r/min.)	

radiation in question, the ratio of exposure times necessary to produce the same effect on screened and unscreened films. This ratio is a measure of the relative efficiency of the screens for this particular type of radiation.

The results of these experiments may be stated briefly. The data for six experiments making direct comparisons of the type shown in Figure 6 are summarized in Table III. In column I is given the number of the experiment, in column II the film density for which the comparison is made. (These densities correspond to the abscissa scale in Figure 6.) Columns III, V and VII give the number of seconds' exposure required to produce the specified density with the different sources of radiation. The variations in these values from one experiment to another are the result of differences in development. Since comparisons are always made within a single experiment, these variations are not significant. The output of the 185 kv. machine, measured in roentgens at the distance used was 0.27 r/min. Column IV gives the total amount of radiation, specified in roentgens, required by this radiation to produce any given blackening. It is now assumed that the same number of roentgens will produce the same blackening, whatever the source, so the data of column IV apply also to the 700 kv. and gamma rays. Therefore, for these radiations, the output in roentgens per minute can be calculated by dividing the total r by the time of exposure in minutes. These values are given in columns VI and VIII for 700 kv. roentgen rays and gamma rays respectively. It will be noted that, in spite of the variations in the experiments, the values arrived at for these outputs agree very well among themselves. Averages have been taken of the data in these two columns and the values reduced to standard conditions. It is found that the output* of the 700 kv. machine as used was 1.0 r/min. at 50 cm., and of the radium pack, 1.18 r/min. at 6 cm.

For the comparison when intensifying screens were used, the data are given in Table IV. It is seen that the efficiency of the screens is much greater with roentgen rays than with gamma rays, being, for 185 kv. roentgen rays, 40; for 700 kv. roentgen

TABLE IV

RELATIVE EFFICIENCY OF INTENSIFYING SCREENS FOR DIFFERENT QUALITIES OF RADIATION

	Density	Time without Screens Sec.	Time with Screens Sec.	Ratio
		185 kv. roentgen rays		
I	0.4	147	4.0	37
	0.5	195	5.0	39
	0.6	246	6.0	41
	0.7	290	7.0	41
II	0.3	226	5.6	40
	0.4	335	8.3	40
	0.5	440	10.0	41
Av.				40
		700 kv. roentgen rays		
I	0.3	480	9	53
	0.4	640	12	53
	0.5	800	15	53
II	0.3	680	13	52
	0.4	900	17	53
	0.5	1110	21	52
Av.				53
		Gamma rays		
I	0.4	173	29	5.9
	0.5	220	35	6.3
	0.6	268	41	6.3
	0.7	316	48	6.5
II	0.4	160	29	5.5
	0.5	200	35	5.7
	0.6	242	40	6.0
	0.7	284	45	6.3
Av.				6.0

* It should be noted that at the time of making this comparison a lower output was used on the 700 kv. machine than when the solutions were being investigated. In order to obtain results for the final table of comparisons, a correction had to be made to allow for this in the ratio of 22/6.85.

rays, 53; for gamma rays, 6.0. That is, in order to produce the same effect on the film with screens, it would require 1/40 as much of the 185 kv. radiation, 1/53 as much of the 700 kv. radiation, and 1/6 as much of the gamma radiation. Thus amounts of radiation of equal photographic

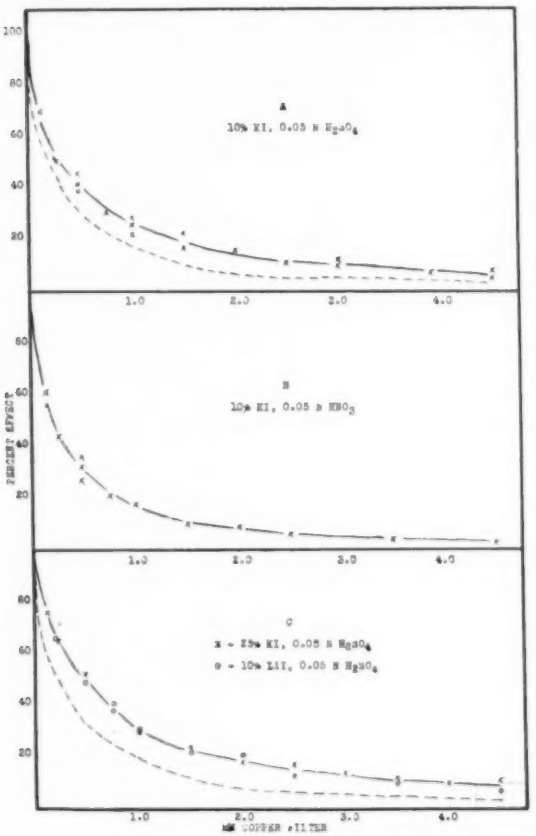

FIG. 8. Absorption curves for different iodide solutions.

effectiveness with the screens could be represented by the equation

$$\frac{1}{40}(185 \text{ kv. x-rays}) = \frac{1}{53} \quad (700 \text{ kv. x-rays})$$

$$= \frac{1}{6} \text{ (gamma rays)}$$

or

$$(185 \text{ kv. x-rays}) = \frac{40}{53} \quad (700 \text{ kv. x-rays})$$

$$= \frac{40}{6} \text{ (gamma rays).}$$

If comparison of the three types of radiation is to be made on this basis, the final values of Table III will have to be changed in accordance with these ratios. The value for the 185 kv. radiation is known, and must be kept constant as 1.62 r/min. at 50 cm. The 700 kv. radiation is more effective in the ratio $\frac{53}{40}$ or its output is apparently higher in this ratio, while that of the gamma rays is lower in the ratio $\frac{6}{40}$. Therefore, the output of the 700 kv. machine measured in this manner, at 50 cm. becomes $1.0 \times \frac{53}{40} = 1.32$ r/min. Similarly, for the radium pack at 6 cm. the output is found to be $1.18 \times \frac{6}{40} = 0.18$ r/min.

ABSORPTION CURVES FOR 200 KV. ROENTGEN RAYS

The effect of comparatively small changes in quality of roentgen radiation has been studied by measuring, with each of the three chemical reactions dealt with in this paper, the changes brought about by increasing thicknesses of copper filter. Figure 8 shows the effect of such differences in filter thickness on iodide solutions irradiated with 200 kv. roentgen rays. The dotted curves represent ionization readings made with a small spherical celluloid ionization chamber (chamber A of Part I). All values are calculated in terms of the effect produced by radiation filtered by 1 mm. of celluloid and no copper as 100 per cent, the tube used being of the thick-walled type so that the glass itself has considerable filtering effect. The curve for solutions containing 10 per cent KI in 0.05 N HNO_3 is practically coincident with the ionization curve. The curves for solutions containing 0.05 N H_2SO_4 all differ from the ionization curve. The curve for 25 per cent KI in 0.05 N H_2SO_4 differs from that for 10 per cent KI in 0.05 N H_2SO_4, but coin-

TABLE V

OUTPUTS OF RADIATION SOURCES IN EQUIVALENT ROENTGENS PER MINUTE AS DETERMINED BY VARIOUS CHEMICALS

Source	10% KI 0.05 N H_2SO_4	10% KI 0.05 N HNO_3	10% LiI 0.05 N H_2SO_4	25% KI 0.05 N H_2SO_4	Eder's Solution	Photographic Films Without Screens	Photographic Films With Screens
165–200 kv.	Measured with "air-wall" ionization chamber						
700 kv. 50 cm.	6.68	5.93	8.09	7.06	12.3	3.1	4.1
Radium pack 6 cm.	3.24	2.52	3.33	2.19	4.4	1.17	0.18

cides with that for 10 per cent LiI in 0.05 N H_2SO_4.

Figure 9 shows the similar curve for Eder's solution, compared with the curves for ionization and for 10 per cent KI in 0.05 N H_2SO_4. The curves for ionization and Eder's solution are very close together, and both differ materially from that for KI.

Figure 10 shows absorption curves for 10 per cent KI in 0.05 N H_2SO_4, for Eder's solution and for photographic films without intensifying screens, the values being calculated in terms of the effect produced with 2.5 mm. copper filters as 100 per cent. The curves for KI and for Eder's solution lie close together, and the curve for KI practically coincides with that for ionization. The curve for photographic effect differs greatly from all the others. It should be noted that the comparison between the effects produced in the solutions and in the photographic film is made for 200 kv.

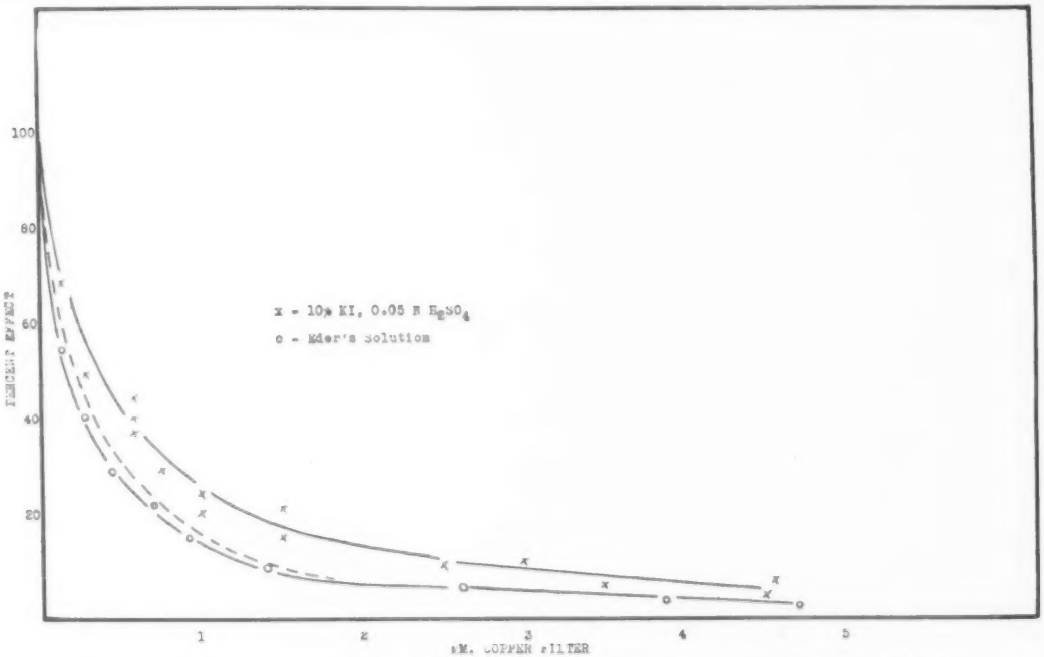

FIG. 9. Absorption curves for Eder's solution and for 10 per cent KI in 0.05 N H_2SO_4.

roentgen rays initially filtered by 2.5 mm. of copper. Additional copper filtration does not change the quality of this radiation very materially and yet the relative effects differ greatly. If the comparison had been made beginning with unfiltered roentgen rays, the difference would have been enormous.

SUMMARY

Potassium and lithium iodide in acid solution, and Eder's solution, are affected

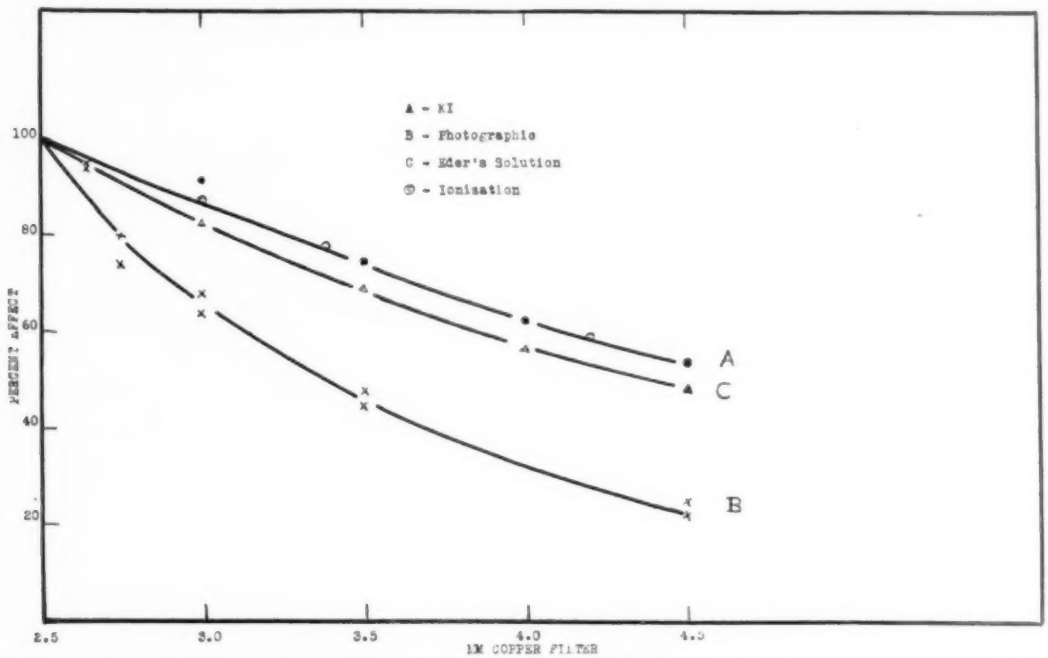

FIG. 10. Absorption curves for 10 per cent KI in 0.05 N H_2SO_4, photographic film and Eder's solution.

to measurable degrees by ordinary roentgen rays, 700 kv. roentgen rays, and gamma rays.

The effect of the radiation results in the liberation of iodine from the iodides, and in the precipitation of mercurous chloride in the Eder's solution.

The amount of iodine liberated can be determined quantitatively by its effect in changing the color of a starch solution.

The amount of the precipitate in Eder's solution can be determined by a simple titration method.

Both reactions give reproducible results, and, by suitable calibration, can therefore be used to measure quantities of radiation. This offers a means of correlating the three qualities of radiation mentioned above, as to their relative effectiveness in producing certain chemical effects.

In order to make possible a direct comparison of the results obtained by chemical means with those obtained by physical and biological tests, the results have been adjusted to represent the radiation emission of the three sources of radiation under certain conditions which have been taken as standard. Since the intensity of ordinary roentgen rays (produced at 165 to 200 kv. in our case) can be expressed in roentgens per minute, the intensities for the other two sources of radiation may be expressed in terms of "equivalent" roentgens per minute, the equivalence being based in each case on the production of the same chemical change. The results expressed in this manner are given in Table v. In this table are also included analogous results obtained by measuring the darkening of photographic films exposed to the same qualities of radiation, with and without the use of intensifying screens.

From this table it is evident that the

apparent radiation emission of the 700 kv. roentgen tube or the radium pack (based on a constant emission for the low voltage source) varies with the chemicals and reactions which are used to determine it. This means, of course, that the relative effectiveness of the three qualities of radiation depends on these factors.*

* For discussion see page 362.

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THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

III. COMPARISON BASED ON EFFECTS ON *DROSOPHILA* EGGS AND ON WHEAT SEEDLINGS*

By P. S. HENSHAW, C. T. HENSHAW, *and* D. S. FRANCIS
Biophysical Laboratory, Memorial Hospital
NEW YORK CITY

INTRODUCTION

IN consideration of the problem of the comparative biological effectiveness of different qualities of radiation, we wish to present here results obtained when wheat seedlings, *Triticum vulgare*, and eggs of the fruit fly, *Drosophila melanogaster*, were used as test objects. When sufficiently large doses of roentgen rays or gamma rays are administered, *Drosophila* eggs are killed and wheat seedlings are retarded in growth. In each case the degree of effect (i.e. the percentage mortality in *Drosophila* eggs and the percentage reduction of linear growth in seedling tissues) is a function of the amount of radiation given. Here, then, are two widely different kinds of responses to radiation appearing in widely different test objects. Since percentage mortality of eggs can be determined by actual count and percentage reduction in growth by direct measurement, both of these responses can be studied quantitatively. As has been shown previously by Cattell[1] and by Failla and Henshaw,[2] newly germinated wheat seedlings present four growing embryonic tissues all of which are retarded by radiation. Thus it is possible to measure one of the responses in four different tissues of the same organism. Having more than one measurable biological response to the radiation, it is possible to express the effect obtained in one in terms of another and compare the different affecting agents directly in biological terms. The question considered in this investigation was this: Are the *same relative effects* produced in different test objects by different qualities of radiation when the intensity, time of exposure, and other conditions of irradiation, are kept the same?

EXPERIMENTAL INVESTIGATION

1. Radiation Used. In the pursuance of this problem we have compared three distinctly different qualities of radiation: (1) 165 kv. roentgen rays, used generally in cancer therapy; (2) 700 kv. roentgen rays, a shorter wave-length radiation, obtained from the new high voltage roentgen tube developed recently by Coolidge, Dempster, and Tanis,[3] and installed at the Memorial Hospital by the General Electric Company, and (3) gamma rays (estimated to be the equivalent of roentgen rays produced at 1,500 kv.), a still shorter wave-length radiation, obtained from a 4-gram radium element pack. Since the quality of radiation is dependent upon wave-length and since the wave-

TABLE I

	165 kv.	700 kv.	Gamma Rays (4 gm. pack)
Ma.	19.25	2.5 to 3.5	
Distance in cm.	50	48.4	6
Filter	1.65 mm. Cu 0.5 mm. Al 2.0 mm. celluloid	Equiv. to 5 mm. Cu + 1 mm. Al 2 mm. celluloid	Equiv. to 2 mm. Pb + 6 mm. bakelite
Intensity	9.5 r/min.		

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

length of roentgen rays is related to the potential applied across the tube, the range of quality of the radiation used can be compared more conveniently on this basis (kv.).

The settings and conditions of exposure used are shown in Table 1. The arrangements of test material for exposure to the different types of radiation are shown in the diagrams (Figs. 1, 2 and 3).

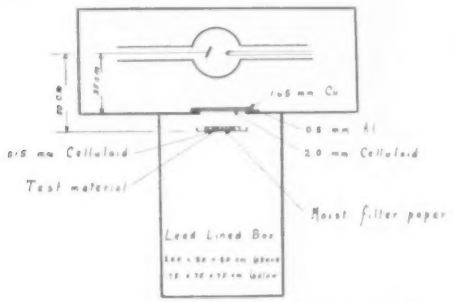


Fig. 1. Diagram showing the position of the test material with respect to filters, source of radiation, etc., when 165 kv. roentgen rays were used.

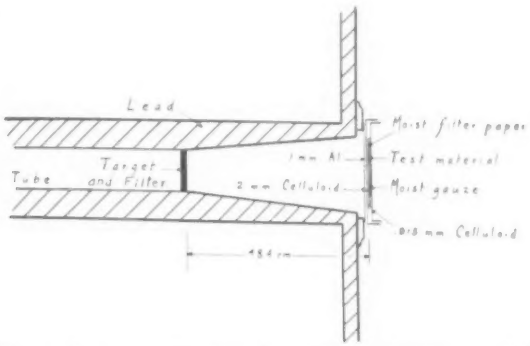


Fig. 2. Diagram showing the position of test material with respect to filters, source of radiation, etc., when 700 kv. roentgen rays were used.

2. Experiments with Wheat Seedlings. The experimental procedure was as follows: Wheat seeds (variety *kota*, obtained from the South Dakota Agricultural Experiment Station) were soaked in tap water for three hours at room temperature. After discarding imperfect seeds, they were carefully placed, groove side down, in closed chambers on wet filter paper. These were put away in a germinating chamber maintained at 19 ° C. Approximately one thousand seeds were planted for a single experiment. About eighteen hours after the seeds had been put to soak the growing tissues were beginning to burst through the seed coats, and it was at this stage that they were exposed to radiation.

In performing the tests only two types of radiation were used at once. That is, on one day tests were carried out with 165 kv. roentgen rays and 700 kv. roentgen rays, on another with 700 kv. roentgen rays and gamma rays, and on still another with 165 kv. roentgen rays and gamma rays, etc. It was necessary, therefore, to arrange two sets of material each time a test was made. These were prepared for irradiation by selecting the most uniform seedlings from the moist chambers and placing them very close together on wet filter paper in shallow trays, which were made by fastening thin

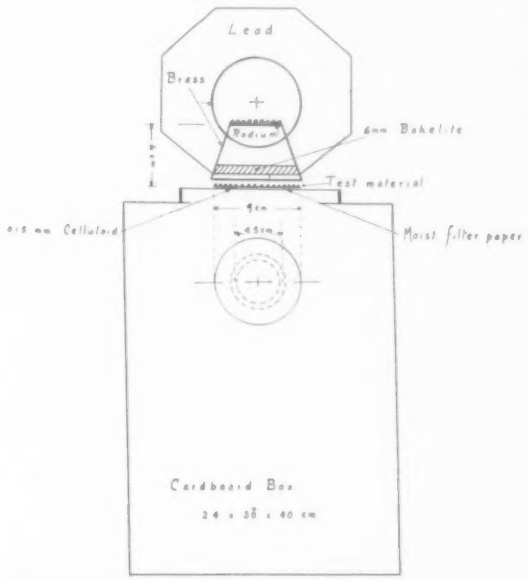


Fig. 3. Diagram showing the position of test material with respect to filters, source of radiation, etc., when gamma rays were used.

celluloid to wooden embroidery hoops. Similar trays, smaller in diameter, were used as covers, thus providing moist chambers for the material while it was being irradiated.

To insure uniformity of results it was necessary to use the same kind of material for all experiments. This was done (1) by rigidly selecting the material; (2) by germinating the seeds for the same length of time under the same conditions, and (3) by performing tests on the same planting of seeds simultaneously.

For the purpose of eliminating the possibility of time-factor effects, intensities of the different types of radiation were adjusted to give approximately the same degree of effect for the same duration of exposure. Preliminary tests were made with gamma rays, the least intense type

of radiation used, to determine the length of exposure necessary to produce measurable effects. The intensities of the other types of radiation were then adjusted to give as nearly as possible the same effects in the same length of time. Having selected certain intensities for use, these were kept constant for all experiments.

The two trays of seedlings, selected from the same planting of seeds, were taken to the sources of radiation and exposures begun simultaneously. Samples were removed after receiving 0, 30, 60, 90, 120 and 180 minutes' exposure. Each sample, consisting of 60 seedlings, was divided into two equal parts and put into moist chambers (15 cm. petri dishes containing wet filter paper). Thus at the end of irradiation there were 24 dishes, each of which contained 30 seedlings. These were placed in a dark thermo-regulated chamber which was main-

TABLE II

Shoot

Min. Exposure	0	30	60	90	120	180
Exp. No.	165 kv. roentgen rays 9.5 r/min.					
4	100	89.5	69.8	56.6	48.2	36.8
5	100	87.2	70.5	57.3	51.0	36.7
7	100	88.5	80.5	68.3	54.9	42.5
9	100	90.8	74.9	52.6	44.7	33.5
11	100	100.0	77.6	61.0	47.9	38.2
12	100	92.2	81.1	70.7	64.5	46.3
13	100	93.0	73.3	63.3	53.7	41.6
17	100	91.5	77.5	65.3	59.4	45.9
19	100	88.7	79.7	67.3	58.3	47.8
20	100	92.3	73.6	58.3	49.0	46.7
22	100	98.1	75.3	63.3	52.0	39.8
23	100	92.5	76.0	59.1	54.6	43.7
24	100	96.5	76.1	61.8	51.9	42.0
Average	100	92.4	75.8	61.9	53.1	41.7
	700 kv. roentgen rays					
20	100	84.5	76.1	57.9	52.3	42.1
22	100	87.3	66.0	52.1	43.3	36.0
23	100	84.4	69.0	59.7	56.2	41.9
24	100	82.9	65.9	47.5	40.6	31.1
Average	100	84.8	69.2	54.3	48.1	37.8
	Gamma rays					
2	100	88.8	69.0	55.8	38.0	34.3
3	100	95.4	80.3	68.2	54.1	44.4
4	100	92.0	78.6	62.7	50.3	39.5
5	100	90.8	71.7	57.4	47.9	37.3
6	100	90.4	72.4	60.1	49.3	42.2
8	100	92.8	83.7	70.1	62.9	48.1
13	100	93.9	83.2	64.5	51.1	40.8
14	100	89.0	75.7	51.6	47.6	37.8
15	100	91.4	77.4	59.6	53.7	37.2
18	100	96.1	75.1	61.9	50.3	37.5
Average	100	92.1	76.7	61.2	50.5	39.9

tained at 19° C. One hundred and twenty hours after the beginning of germination the young plants were removed and measurements were made of the linear growth of the four embryonic tissues. Occasionally in handling the material a growing tip is injured in such a way that little or no growth occurs in the part affected. Therefore only 20 of the most uniform seedlings in each dish were measured.

The four embryonic parts of the wheat seedling, the *sheath*, *shoot*, *primary* and *secondary roots* (Fig. 4), have been described previously.[2] Results were obtained for all of these but shown in detail for the shoot only (Table II), the nature and extent of variability of which are generally characteristic for all. The average values obtained for the shoot were plotted in Figure 5. Such curves make it possible to compare directly the effects obtained with the different kinds of radiation either in terms of effect produced by certain exposures or in terms of exposure required to produce a certain degree of effect in each case. The latter method was used.

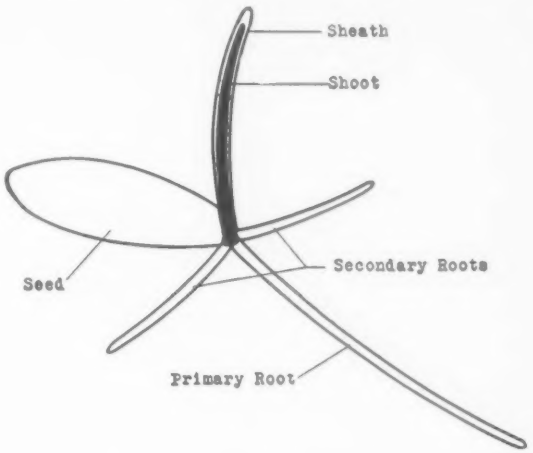
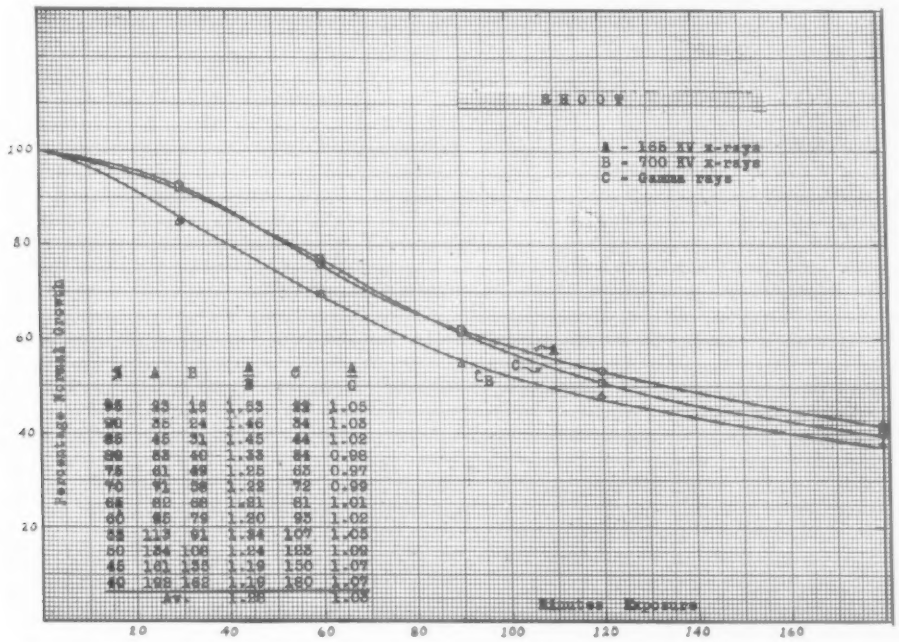


FIG. 4. Diagram of wheat seedling showing embryonic parts.



%	A	B	A/B	C	A/C
95	23	18	1.33	22	1.05
90	35	24	1.46	34	1.05
85	45	31	1.45	44	1.02
80	53	40	1.33	54	0.98
75	61	49	1.25	63	0.97
70	71	56	1.27	72	0.99
65	82	68	1.21	81	1.01
60	95	79	1.20	93	1.02
55	113	91	1.24	107	1.05
50	134	106	1.26	125	1.09
45	161	135	1.19	156	1.07
40	198	162	1.19	180	1.07
	Av.		1.28		1.05

FIG. 5. Curves showing the effects of 165 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays, on the shoot of the wheat seedling.

Readings of dosages were taken along the curves and arranged in tables (see inset table for shoot, Fig. 5). In columns A, B, and C dosages are shown in minutes' exposure required to cause various corresponding amounts of reduction in growth for 165 kv. roentgen rays, 700 kv. roentgen rays and gamma rays, respectively. It is seen that the values in column A and C are very similar while those in column B are generally lower. Further comparison was made on a relative basis, dividing the values in column A by the corresponding values in B and C. The relative values or ratios are shown in columns A/B and A/C. Approximately the same difference occurs throughout

the extent of the curves. Since the ratios in either column A/B or A/C vary but little the small variations are probably due to experimental errors. Thus the general differences between the curves are best indicated by averages of the values in the columns A/B and A/C. These are shown at the bottom of the table. They indicate that the intensity of 165 kv. roentgen rays and gamma rays had been adjusted to produce, in the same time of exposure, practically identical effects in the shoot, but that the intensity of 700 kv. roentgen rays was somewhat high. The difference, however, introduces no complication in the present investigation.

Average values for the sheath, primary root, and secondary root, have been obtained in precisely the same way and have been brought together with those for the shoot in Table III for comparison. Since the experimental conditions varied only with respect to quality of radiation used, any differences in relative values obtained for a given tissue, if well established, must be attributed to this factor. The results obtained for the sheath show that equal effects were produced by 165 kv. roentgen rays and gamma rays for equal exposures. Had the intensity of 700 kv. roentgen rays been adjusted to produce equal effects on the sheath in the same time of exposure as in the case of the other two qualities of radiation, the ratios would have been those given in parentheses in the table. This adjustment enables us to relate the effects produced in the different times by the three qualities of radiation to those produced in the sheath taken as a standard.

The ratios of exposure for 165 kv. roentgen rays and gamma rays are similar for all of the tissues, the maximum difference being 7 per cent. If the differences are actually due to quality of radiation, a similar differential effect of lesser degree should be obtained for 700 kv. roentgen rays, since their quality, as indicated above, is between that of the other radiations. As seen in Table III, the values for 700 kv. roentgen rays vary in a direction directly opposite to those for gamma rays. Therefore, since the differences observed are small and since they are not consistent for different radiations, it seems best to attribute them (at least for the present) to experimental variation rather than to quality of radiation. For further comparison, then, averages for all of the tissues will be used (see Table III).

TABLE III

Tissue	Ratios of Exposure Times		
	165 kv. roentgen rays / 165 kv. roentgen rays	165 kv. roentgen rays / 700 kv. roentgen rays	165 kv. roentgen rays / gamma rays
Sheath	1.00	1.43 (1.00)	1.00
Shoot	1.00	1.28 (.89)	1.03
Primary root	1.00	1.25 (.87)	1.07
Secondary root	1.00	1.14 (.80)	1.06
Av.	1.00	1.29	1.04

3. Experiments with Drosophila Eggs. Having found certain effects caused in the wheat seedlings by different kinds of radiation maintained at certain intensities, the next step was to determine whether the *same relative effects* would be caused in *Drosophila* eggs when exposed under the same conditions. For this purpose flies were cultured as described previously[4] and eggs were collected for the experiments during two hour periods from actively laying flies. Each collection of eggs used was divided into two parts in order that two kinds of radiation could be used on the same material. For convenience in handling, these two parts were subdivided into eight others and spread evenly on small, moist, filter paper strips. These *egg samples* were arranged in trays and irradiated in the same way as the seedlings, using the same intensities, except where otherwise indicated. Samples were removed after receiving 0, 10, 20, 25, 30, 35, 40 and 50 minutes' exposure and put away in moist chambers at room temperature (22–25° C.). Normally, the eggs hatch in twenty to thirty hours. Counts were therefore made on the third day after irradiation to determine the number of eggs surviving to the hatching stage.

Results were obtained for the three types of radiation but are given in detail for gamma rays only. These are shown in Table IV with percentage of controls hatching in each experiment taken as 100 per cent (the fertility of the controls ranging from 92 to 98 per cent). The data in this table are sufficient to indicate the

TABLE IV

Drosophila Eggs—Gamma Rays

Min. Exposure	0	10	20	25	30	35	40	50
Exp. No.	Percentage Eggs Hatching							
24	100	94.0	66.4	56.5	44.4	42.3	31.0	27.1
25	100	101.5	72.7	47.4	42.5	36.0	37.0	29.2
26	100	96.7	68.4	61.7	44.2	35.3	28.5	25.3
28	100	102.8	82.3	70.1	57.8	54.6	43.2	31.9
29	100	94.1	77.4	64.2	56.6	52.9	41.3	32.4
30	100	96.8	64.0	62.1	57.8	41.2	39.5	25.2
31	100	99.5	69.8	65.2	53.9	42.8	46.5	28.0
33	100	99.2	65.1	50.0	33.1	29.6	32.2	25.8
35	100	96.0	66.4	52.2	49.8	39.5	33.6	22.8
36	100	97.6	65.7	56.8	42.8	37.2	31.1	22.8
37	100	96.9	69.4	59.8	49.3	38.6	31.6	22.4
Average	100	97.7	69.8	58.7	48.4	40.9	36.0	26.6

extent of variation in the results as obtained. Average values are shown at the bottom of the table. These have been plotted in Figure 8. Similar averages for 165 kv. roentgen rays and 700 kv. roentgen rays are plotted in Figures 6 and 7 respectively. Before determining the relationship of these curves, however, it was necessary to make two minor corrections in order to compare the *Drosophila* egg results directly with those for the seedlings. First, because of adjustments made on the 700 kv. roentgen tube the intensity of radiation used for the eggs was 5 per cent less than that used for the seedlings, as shown by ionization measurements. It was necessary, therefore, to shift the curve in Figure 7 to the left to compensate for this. The broken line curve shows the proper correction. Second, when exposing the seedlings to gamma rays it was necessary to cover the moist filter paper completely with seeds (see Fig. 3) in order to have enough for a complete experiment. As shown previously,[2] the intensity at the center of this field is greater than at the periphery. When samples of seedlings were removed, they were selected uniformly from the field in order that all samples would be affected alike. When working with *Drosophila* eggs the samples were placed in a circle in such a way that all were an equal distance from the center and half way between the cen-

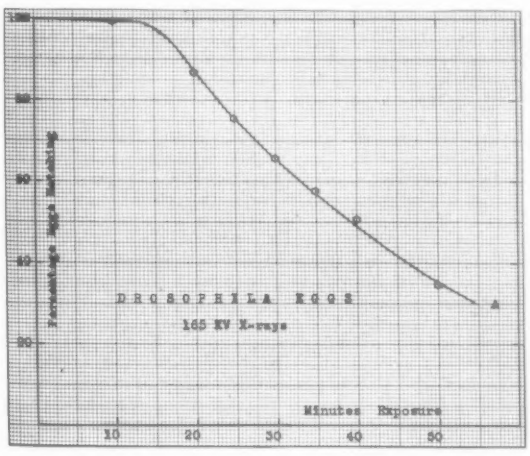


FIG. 6. Curve showing the effects of 165 kv. roentgen rays on *Drosophila* eggs.

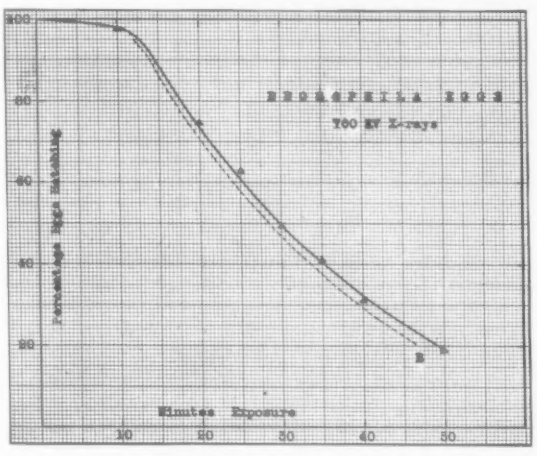


FIG. 7. Curve showing the effects of 700 kv. roentgen rays on *Drosophila* eggs.

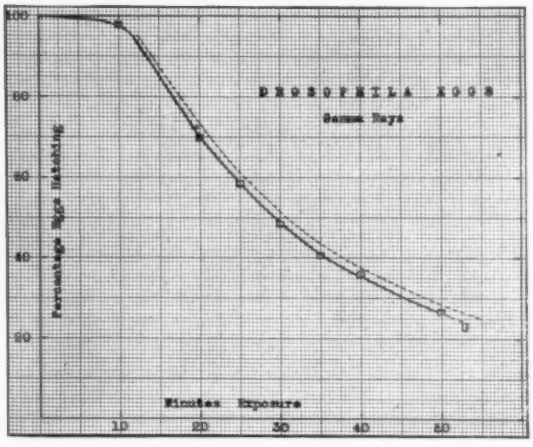


FIG. 8. Curve showing the effects of gamma rays on *Drosophila* eggs.

ter and periphery. This provided equal intensities for all samples of eggs, but it was found by calculations based on data given before[2] that the eggs in this position received a little higher intensity than the average intensity received by the seedlings. To make the two sets of results directly comparable the curve in Figure 8 was shifted to the right, as indicated by the broken line.

Readings of dosages required to produce various degrees of effect were then taken from the curve for 165 kv. roentgen rays and from the corrected curves for 700 kv. roentgen rays and gamma rays in the same way as described for the shoot of the wheat seedling. The exposure times and ratios as well as the final averages are shown in Table v. Here again the curves are found to be similar in shape since the ratios are substantially constant throughout the range of exposures. The values for 700 kv. roentgen rays (B) and gamma rays (C) are generally lower than those for 165 kv. roentgen rays (A), thus indicating that smaller amounts of these radiations were required to produce equal effects. The averages show that 30 and 37 per cent shorter exposures to the 700 kv. roentgen rays and gamma rays, respectively, were necessary. To determine whether the same relative effects were produced in the eggs and seedlings, the average values in Tables III and V may be compared. These are arranged together in Table VI. For convenience in comparison, the values in parentheses have been adjusted to appear as they would had the intensities of the three different qualities of radiation given identical effects in the wheat seedlings for the same time of exposure.

TABLE V

Drosophila Eggs

Per cent	A	B	$\frac{A}{B}$	C	$\frac{A}{C}$
95	16.7	12.3	1.36	12.1	1.38
90	18.9	14.2	1.33	13.8	1.37
85	20.9	15.8	1.32	15.4	1.36
80	23.0	17.5	1.31	16.9	1.36
75	25.2	19.3	1.31	18.5	1.36
70	27.7	21.1	1.31	20.2	1.37
65	30.3	23.2	1.31	22.5	1.35
60	33.0	25.6	1.29	24.1	1.37
55	36.1	28.2	1.28	26.2	1.38
50	39.2	30.9	1.27	28.3	1.38
45	42.6	34.0	1.25	30.8	1.38
40	46.2	37.6	1.26	33.5	1.38
35	50.2	42.6	1.18	36.4	1.38
30	55.0	47.8	1.15	39.5	1.39
Average			1.30		1.37

DISCUSSION

According to the results presented, 165 kv. roentgen rays and 700 kv. roentgen rays are about equally effective in producing mortality in *Drosophila* eggs when intensities are measured by the effect produced in wheat seedlings. On the same basis gamma rays are 32 per cent more effective than either of these types, thus indicating a larger differential effect. Having found that gamma rays under these conditions are more effective than 165 kv. roentgen rays, the question arises as to why 700 kv. roentgen rays produce effects so much like those for 165 kv. roentgen rays when their quality is distinctly different.

By a careful examination of the data, reasons are found for believing that the ratio in Table VI for *Drosophila* eggs, irradiated with 700 kv. roentgen rays, should be higher than 1.30. The last two values in the A/B column of Table V are considerably below the average. Turning to Figure 7 it will be seen that these are dependent upon a single experimental point at the lower end of the curve. Since the greatest variation usually occurs in this region, the results are probably abnormally low. Also attention may be called to the fact that the ratio for seedlings irradiated with 700 kv. roentgen

rays (Table VI) is based on results of only four experiments, while all others, including those for the eggs, are based on from ten to fifteen. The small number of experiments may therefore account for the variation in the ratios obtained for the different tissues exposed to 700 kv. roentgen rays (see Table III). Here it is seen that the values for the sheath, a tissue which is little affected by the radiation, are very high when compared with those for the other tissues. This makes the average value for 700 kv. roentgen rays appear higher than it otherwise would. If either of these conditions should be abnormal as suggested, the ratio in Table VI for *Drosophila* eggs irradiated with 700 kv. roentgen rays would be increased by any correction applied. This would make it intermediate to the values for the other two kinds of radiation. In this form, then, the results would indicate a graded differential effect from 165 kv. roentgen rays to gamma rays.

TABLE VI

Material	Ratios of Exposure Time		
	165 kv. roentgen rays / 165 kv. roentgen rays	165 kv. roentgen rays / 700 kv. roentgen rays	165 kv. roentgen rays / gamma rays
Seedlings	1.00	1.29 (1.00)	1.04 (1.00)
Eggs	1.00	1.30 (1.01)	1.37 (1.32)

But how significant is the differential effect which has been attributed to quality of radiation? The greatest difference in effect obtained in a very favorable test (widely different types of biological responses as criteria of effects, widely different test objects, and widely different qualities of radiation) was .32 per cent. From this, then, it appears that the quality factor is not very important. Since the difference is little beyond that which must be accepted as experimental variation, these results, taken alone, do not prove that differential biological effects are caused by different qualities of radiation.

SUMMARY

1. The biological effectiveness of 165 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays, has been compared in wheat seedlings and *Drosophila* eggs.

2. A differential effect was obtained, but considering the fact that widely different responses, test objects, and qualities of radiation, were used it is too small to be significant.*

NOTE: For purposes of comparing these results directly with others presented in this symposium, they may be expressed in terms of "equivalent" intensities, in roentgens per minute of the three types of radiation, based on the effects produced on the wheat seedlings and *Drosophila* eggs. The intensity of the 165 kv. roentgen rays as used was 9.5 roentgens per minute when measured in accordance with the requirements of the definition of the international unit of roentgen radiation. Since the results obtained with the seedlings indicate that the intensities of 700 kv. roentgen rays and gamma rays were 1.29 and 1.04 times as effective, respectively, and since *Drosophila* eggs indicate in the same way that these radiations were 1.30 and 1.37 times as effective (see Table VI), the radiation intensities may be calculated easily. They are given below for a distance of 50 cm. in case of the 700 kv. roentgen rays and 6 cm. in case of the radium pack.

	165 kv.	700 kv.	Gamma Rays
Wheat seedlings	9.5	12.2	9.9
Drosophila eggs	9.5	12.3	13.0

The authors wish to express their indebtedness to Dr. G. Failla who has been instrumental in prompting an extensive investigation of the general aspects of this problem and whose interest and advice have been of value in the present work.

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* For discussion see page 362.

THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

IV. COMPARISONS BASED ON BIOLOGICAL CHANGES PRODUCED IN MAMMALIAN TISSUES WITH 200 KV. ROENTGEN RAYS AND GAMMA RAYS*

By HALSEY J. BAGG, PH.D., *and* C. ROBERT HALTER, PH.D.
Douglas Research Laboratory, Memorial Hospital and Cornell University Medical College
NEW YORK CITY

THE symposium, of which this paper is a part, deals with the relative effects produced by 200 kv., and 700 kv. roentgen rays, and gamma rays of radium. The results have been accumulated by various experimental and clinical studies. The purpose of this paper is to summarize the experimental results obtained by irradiating essentially similar mammalian tissues with 200 kv. roentgen rays and gamma rays and to discuss the relative effectiveness of the agents employed.

EXPERIMENTAL METHODS

A segment of a growing mouse tail and the ear of an adult rabbit were used as test materials.

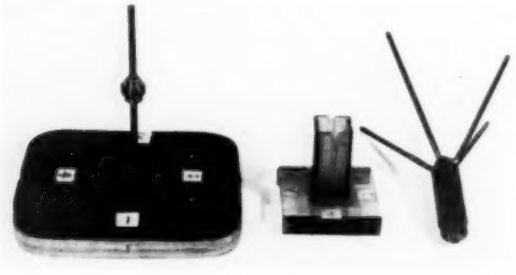

FIG. 1. Radon applicator for the treatment of 4 animals simultaneously. (The assembled unit is shown to the left in Fig. 2.) To the left is the base with a vertical brass rod at the top of which is a depression for the radon bulb. The center shows the celluloid frame with the tapering grooves for the tails. At the right is a central metal case which fits inside the celluloid frame and then is placed over the brass rod. The four radiating rods support the frames on which the bodies of the mice are held. For further details, see text.

The methods employed for the use of the mouse tail for radon radiation have been described in previous publications to which reference may be made for further details.[1,2] In brief, the procedure is as follows. A special applicator made it possible to treat 4 animals at a time. The details of construction are given in Figures 1 and 2. The mice were seven to nine days of age when treated. The tails were arranged at a distance of 10 mm. about a central source of radiation. The radon was contained in a small glass bulb placed in a hollow in the

FIG. 2. At the right is the applicator for treating small areas of the rabbit's ear. At the top of the lead cylinder is a concavity for the radon bulb. The base is of celluloid. For further details, see text. At the left is the assembled unit of Figure 1.

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932. This investigation has been aided by a grant from the Committee on the Effects of Radiation upon Living Organisms of the National Research Council.

central core of the applicator (see Fig. 1). Additional filter was added as part of the section to which the tails were fixed. The total filter was 2 mm. of brass and 3 mm. of bakelite. Two sections of a lead cylinder were arranged to shield the proximal and distal portions of the tail. The cylinders were separated so that 10 mm. of the central portions of the tail was treated. The tails were inserted into grooves filed into the celluloid casing surrounding the lead cylinders. A thin sheet of celluloid covered the inner surface of the groove. The dorsal surface of the tail faced the radon.

The glass radon bulb was also used for the treatment of the rabbit ear. The radon was placed in a hole drilled in the top of a cylinder of lead, 16 mm. in diameter, and 17 mm. in height (Fig. 2, right). At the bottom of the lead cylinder a hole 8 mm. in diameter and 14 mm. in depth was drilled. At the top of the cavity a cup-shaped piece of brass held the radon, which was inserted from above. The filter was 2 mm. of brass and the distance from the center of the source of radiation to the rabbit's ear was 12 mm. A plate of celluloid 2 mm. thick was fastened into the cavity through which the radiation passed in order to remove as much secondary radiation as possible. The whole applicator was mounted on a thick piece of celluloid which distributed the weight over the rabbit's ear. The applicator was strapped to the ear by adhesive strips. The rabbit was held in a box with its head protruding from one end, and its ear drawn forward over a shelf of celluloid to which the ventral surface was fastened. The applicator was placed on the dorsal surface.

A preliminary study was made of the tissue reaction occurring in the rabbit's ear following exposure of a relatively large area to the so-called radium element pack which contains 4 grams of radium. The construction of this apparatus has been described by Failla.[3] The rabbit was held as for the radon treatments and, in addition, a sheet of celluloid 2 mm. thick was placed over the dorsal surface of the ear. With the ear held tightly between celluloid plates, the radium pack was lowered to barely touching the upper piece of celluloid. This brought the center of the source of radiation to 6.2 cm. from the dorsal surface of the ears. Approximately 9 cm. of the distal portion of the ear was irradiated, or approximately 44 sq. cm. The lead to the sides of the applicator and lead over the box adequately shielded the rest of the rabbit.

A study was made of the tissue reaction following roentgen irradiation of a relatively small area of the rabbit's ear. The rabbit was held in the same apparatus used for the radium element pack treatments. A lead shield 3 mm. thick was then placed over the upper sheet of celluloid. In this lead, holes 8 mm. in diameter provided for the radiation exposure.

A preliminary study was made of the treatment of relatively large areas (approximately 28. sq. cm.) of the rabbit's ear by roentgen rays. The rabbit was held as above but only the distal and proximal regions of the ear were protected by lead. This left a band of tissue approximately 4.8 cm. wide which was exposed to the rays.

The roentgen applicator for the treatment of the mouse tail is shown in Figure 3. A piece of celluloid 2 mm. thick and 24 cm. square is fastened to a wooden frame and raised 11 cm. above the surface on which the frame rests. Rectangular sections were cut in the celluloid sheet. From these sections were filed grooves into which the tails were placed. The mice were fastened to lead blocks which were placed over the window-like openings in the celluloid. After the animals were so placed, a circular lead shield with six openings (see Fig. 3) was placed over the tails. This made it possible to treat the central segment of 6 tails simultaneously. The lead shield was approximately 2.5 mm. thick

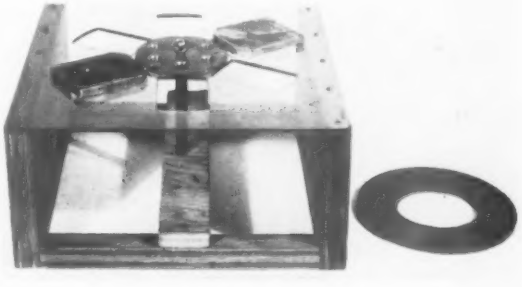

Fig. 3. Roentgen-ray apparatus for the treatment of 6 animals simultaneously. The mice are fastened to the lead plates (two are shown) with their tails in grooves cut in the large celluloid sheet which is held by the wooden frame. The tail segments are irradiated through the holes cut in the central round lead disk. After all are in place, the lead disk shown at the right is placed so that it covers the space between the lead shields and the central circular plate. For further details, see text.

and the holes through which the treatments were given were 10 mm. in diameter. A thin sheet of celluloid was fastened over the entire lower surface of the shield to absorb the secondary radiation. The dorsal surface of the tail faced the roentgen rays. A ring of lead 5 mm. thick and approximately 22 mm. wide was placed over the lead shield and the blocks holding the bodies of the mice (see Fig. 3). This shielded the base of the tails where the shield and the blocks came together.

EXPERIMENTAL RESULTS

1. *The radon bulb on the tails of young mice.* (Filter, 2 mm. of brass, 3 mm. of bakelite; distance, 10 mm.; intensity of radon at the middle of the treatment period in different experiments varied from 245 to 550 mc., the average being 446 mc.)

Sixty-five animals were treated with doses varying from 50 to 750 mc-hr.

Table 1 gives a summary of results and shows the number of the animal, the millicurie-hours, the maximum tissue reaction (and the day post-treatment on which it occurred), and the final tissue reaction when the experiment was terminated on the thirty-fifth day.

With doses from 50 to 100 mc-hr. the final tissue reaction varied from a slight epilation followed by a return of hair in the lower doses, to a partial epilation of the dorsal surface of the tail and a slight ventral epilation at 100 mc-hr.

Doses from 150 to 350 mc-hr. show a gradual increase in the severity of the tissue reaction, and at 350 mc-hr. there is approximately complete annular epilation. This threshold dosage for complete annular epilation of the tail is the point we have taken for comparing reactions following different methods of treatment.

Nine animals were treated with a dose of 400 mc-hr. and all showed a maximum tissue reaction of complete annular epilation appearing from the fourteenth to the twentieth day post-treatment. For final reaction on the thirty-fifth day 2 animals showed a very slight return of hair on the ventral surface, 8 in which the epilation remained complete, and one in which the tail showed pathological amputation.

Doses above 400 mc-hr. show an increase in the severity of the tissue reactions, which range from complete annular epilation to sharp constriction of the tail, which is a step on the way to the next severe reaction, namely, pathological amputation of the tail.

2. *Roentgen treatment of the tails of young mice.* (200 kv.; filter, 0.5 mm. copper, 0.8 mm. aluminum and 2.5 mm. celluloid; distance, 50 cm.; 62 r per min.)

Eighty animals were treated in doses ranging from 400 to 5000 r. The results are given in Table II. The threshold dosage for complete annular epilation is approximately 2350 r, but in order to economize on table space the results are given in detail to 2600 r only.

Two doses of 400 r showed apparently complete return of hair after a slight annular epilation. Six treatments of 500 r each showed a moderate epilation followed by a partial return of hair. Doses from 1000 r to 2300 r inclusive show an increase in the maximum tissue reaction to practically complete annular epilation, but in seven of the ten higher doses there is a slight return of hair on the ventral surface by the thirty-fifth day post-treatment.

From 2350 r and higher the maximum reaction is complete annular epilation with or without constriction of the tail and pathological amputation.

The final reaction for six 2350 r treatments is annular epilation except in 2 instances where a very slight return of ventral hair was noted. In the case of 24 treatments of 2500 r each the final tissue reaction is complete annular epilation in 8 instances, 2 of which show constriction of the tail as well, and in 2 instances there is a return of ventral hair, one very slight, and one moderate. Fourteen tails showed pathological amputation occurring from sixteen to twenty days post-treatment.

In the 29 treatments ranging from 2600 r to 5000 r the final tissue reaction is above the threshold for annular epilation with

TABLE I

SUMMARY OF RESULTS OF THE TREATMENT OF THE GROWING MOUSE TAIL BY THE RADON BULB

Animal No.	Dosage in mc-hr.	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 35th Day Post-Treatment
1139	50	5% annular epilation ..... 19d.	Same
1096	75	10% dorsal, 5% ventral epilation ..... 24d.	Same
1360	75	25% dorsal, 10% ventral epilation ..... 8d.	5% annular epilation
1357	75	10% annular epilation ..... 11d.	5% annular epilation
1068	100	90% dorsal, 5% ventral epilation ..... 28d.	Same
1138	100	75% dorsal, 10% ventral epilation ..... 19d.	50% dorsal, 10% ventral epilation
1091	100	10% annular epilation ..... 25d.	10% dorsal epilation
1358	100	90% dorsal, 25% ventral epilation ..... 18d.	10% annular epilation
1359	100	95% dorsal, 50% ventral epilation ..... 27d.	25% dorsal, 5% ventral epilation
1095	150	50% dorsal, 25% ventral epilation ..... 24d.	20% dorsal, 10% ventral epilation
1362	150	50% annular epilation ..... 22d.	25% dorsal, 10% ventral epilation
1361	150	75% dorsal, 50% ventral epilation ..... 18d.	25% dorsal, 10% ventral epilation
1094	175	90% annular epilation ..... 17d.	50% dorsal, 10% ventral epilation
1364	175	50% dorsal, 25% ventral epilation ..... 14d.	50% dorsal, 10% ventral epilation
1363	175	75% annular epilation ..... 18d.	75% annular epilation
1137	200	90% dorsal, 75% ventral epilation ..... 15d.	15% dorsal, 25% ventral epilation
1090	200	90% dorsal, 75% ventral epilation ..... 25d.	75% dorsal, 50% ventral epilation
1368	200	90% annular epilation ..... 18d.	75% dorsal, 25% ventral epilation
1089	250	90% annular epilation ..... 25d.	90% dorsal, 50% ventral epilation
1367	250	95% annular epilation ..... 18d.	75% dorsal, 10% ventral epilation
1366	250	90% annular epilation ..... 18d.	90% dorsal, 50% ventral epilation
1123	300	100% dorsal, 90% ventral epilation ..... 27d.	90% dorsal, 80% ventral epilation
1136	300	100% annular epilation ..... 15d.	100% dorsal, 50% ventral epilation
1088	300	100% dorsal, 95% ventral epilation ..... 25d.	100% dorsal, 90% ventral epilation
1135	325	100% dorsal, 90% ventral epilation ..... 19d.	100% dorsal, 75% ventral epilation
1134	350	100% annular epilation ..... 26d.	100% dorsal, 95% ventral epilation
1093	350	100% annular epilation ..... 24d.	100% dorsal, 90% ventral epilation
1124	350	100% annular epilation ..... 21d.	Same
1132	400	100% annular epilation ..... 15d.	Same
1125	400	100% annular epilation ..... 16d.	Same
1087	400	100% annular epilation ..... 14d.	Same
1071	400	100% annular epilation ..... 17d.	100% dorsal, 90% ventral epilation
1131	400	100% annular epilation ..... 15d.	100% dorsal, 95% ventral epilation
1210	400	Amputation ..... 18d.	Same
1211	400	100% annular epilation ..... 20d.	Same
1212	400	100% annular epilation ..... 20d.	Same
1238	400	100% annular epilation ..... 15d.	Same
1086	450	Amputation ..... 25d.	Same
1126	450	Constriction ..... 21d.	Same
1130	450	100% annular epilation ..... 15d.	Same
1085	475	100% annular epilation ..... 14d.	Same
1063	500	Amputation ..... 20d.	Same
1084	500	Amputation ..... 23d.	Same
1127	500	100% annular epilation ..... 16d.	Constriction
1128	500	100% annular epilation ..... 15d.	Same
1463	500	100% annular epilation ..... 35d.	Same
1464	500	Constriction ..... 25d.	Same
1465	500	Amputation ..... 23d.	Same
1466	500	Amputation ..... 23d.	Same

TABLE II

SUMMARY OF RESULTS OF TREATMENT OF GROWING MOUSE TAIL WITH 200 KV. ROENTGEN RAYS

Animal No.	Dosage in roentgens	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 35th Day Post-Treatment
1161	400	25% annular epilation....26d.	Recovery
1172	400	25% dorsal, 5% ventral epilation....14d.	Recovery
1165	500	75% annular epilation....26d.	50% dorsal epilation
1329	500	50% annular epilation....24d.	25% dorsal, 10% ventral epilation
1330	500	50% annular epilation....16d.	50% dorsal, 25% ventral epilation
1332	500	50% annular epilation....24d.	50% dorsal, 20% ventral epilation
1333	500	50% annular epilation....16d.	50% dorsal, 25% ventral epilation
1334	500	50% annular epilation....24d.	50% dorsal, 25% ventral epilation
1164	1000	95% annular epilation....19d.	10% dorsal epilation
1171	1000	95% annular epilation....21d.	5% dorsal epilation
1163	1400	95% annular epilation....19d.	40% dorsal, 10% ventral epilation
1169	1800	100% annular epilation....16d.	90% annular epilation
1162	1800	100% dorsal, 95% ventral epilation....21d.	90% annular epilation
1159	2000	100% dorsal, 95% ventral epilation....24d.	95% dorsal, 75% ventral epilation
1166	2000	100% annular epilation....19d.	95% annular epilation
1397	2000	100% annular epilation....24d.	95% annular epilation
1241	2200	100% annular epilation....15d.	100% annular epilation
1244	2200	95% annular epilation....12d.	95% annular epilation
1243	2300	100% annular epilation....17d.	100% annular epilation
1240	2300	100% annular epilation....15d.	100% annular epilation
1158	2300	100% annular epilation....17d.	100% dorsal, 95% ventral epilation
1424	2350	100% annular epilation....16d.	100% dorsal, 95% ventral epilation
1425	2350	100% annular epilation....16d.	100% annular epilation
1426	2350	100% annular epilation....21d.	100% annular epilation
1430	2350	100% annular epilation....17d.	100% annular epilation
1431	2350	100% annular epilation....17d.	100% annular epilation
1432	2350	100% annular epilation....17d.	95% annular epilation
1202	2500	Constriction....16d.	Constriction
1203	2500	Amputation....35d.	Same
1204	2500	100% annular epilation....16d.	100% annular epilation
1205	2500	Amputation....18d.	Same
1206	2500	Amputation....16d.	Same
1213	2500	Amputation....16d.	Same
1214	2500	Amputation....16d.	Same
1215	2500	Amputation....16d.	Same
1216	2500	Amputation....19d.	Same
1217	2500	Amputation....18d.	Same
1218	2500	Amputation....20d.	Same
1221	2500	Amputation....19d.	Same
1223	2500	Amputation....19d.	Same
1227	2500	Amputation....17d.	Same
1228	2500	Amputation....19d.	Same

one exception where for a treatment of 2600 r the peak reaction was complete annular epilation, but the ventral hair returned by the thirty-fifth day post-treatment.

The threshold for annular epilation in this experiment is approximately 2350 r.

3. *The radon bulb on the ear of an adult rabbit.* (Area treated, 8 mm. in diameter; filter, 2 mm. brass +2 mm. celluloid; dis-

tance, 12 mm.; average intensity of the radon at the middle of the treatment, 398 mc.)

Eleven treatments were given, ranging from 200 to 2700 mc-hr. A summary of the results is shown in Table III, which gives the maximum tissue reaction, the day on which it occurred, as well as the reaction ninety days post-treatment.

area of the rabbit's ear. (200 kv.; filter, 0.5 mm. copper, 0.8 mm. aluminum and 2.5 mm. celluloid; distance, 50 cm.; 62 r per minute; area treated approximately 28 sq. cm.)

The results for this experiment using rabbits' ears are also preliminary as only four treatments have been completed. The exposures appear well selected and the

TABLE III

IRRADIATION OF RABBIT'S EAR BY RADON
(Small area treated)

Animal No.	Dosage in mg-hr.	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 90th Day Post-Treatment
12	200	70% epilation both surfaces.....97d.	70% dorsal epilation
12	250	90% dorsal, 10% ventral epilation....75d.	90% dorsal epilation
1	274	100% dorsal epilation.....53d.	85% dorsal epilation
12	300	100% epilation both surfaces.....85d.	100% epilation both surfaces
12	350	100% epilation both surfaces.....47d.	95% dorsal, 100% ventral epilation
2	375	100% epilation both surfaces.....26d.	90% dorsal, 95% ventral epilation
2	450	100% epilation both surfaces.....40d.	95% dorsal, 90% ventral epilation
1	486	100% epilation both surfaces.....36d.	95% dorsal, 95% ventral epilation
1	834	100% epilation both surfaces.....33d.	100% epilation both surfaces
3	1500	100% epilation both surfaces.....34d.	100% epilation both surfaces
12	2700	100% epilation both surfaces with ulcer.23d.	100% epilation both surfaces

The maximum tissue reactions show that the 200, 250 and 274 mc-hr. treatments resulted in incomplete epilation for both surfaces of the treated area. At ninety days post-treatment there is a very slight return of hair over the irradiated region.

4. *Roentgen treatment of a relatively small area of the ear of an adult rabbit.* (200 kv.; filter, 0.5 mm. copper, 0.8 mm. aluminum and 2.5 mm. celluloid; distance, 50 cm.; 62 r per min.; area treated approximately 50 sq. mm.)

Seventeen treatments were given ranging from 100 r to 5000 r. The results are shown in Table IV. The threshold dose for complete epilation of both surfaces of the ear is approximately 1800 r. Doses of 1500 r and 1750 r are slightly below this tissue reaction, while doses of 2000 r, and above, give complete epilation at ninety days post-treatment.

5. *Roentgen treatment of a relatively large* threshold dosage for complete epilation of both surfaces of the ear may be estimated at 1800 r (see Table V). Fifteen hundred roentgens gives a maximum tissue reaction of approximately two-thirds epilation of just the dorsal surface of the ear, while 2000 r produces complete epilation of both surfaces. We therefore approximate the threshold dosage at 1800 r. The largest dose of 3000 r completely destroyed a large portion of the treated area.

6. *Irradiation of a relatively large area of the rabbit's ear by the radium element pack.* (4 grams of radium; filter equivalent to 2 mm. lead and 2 mm. celluloid; distance, 6.2 cm.)

The results here are also preliminary, as only four treatments were completed. They ranged from 15,000 to 32,000 mg-hr., as shown in Table VI. The threshold for complete epilation of both surfaces of the ear is roughly 15,000 mg-hr. At the fifty-fifth

TABLE IV

ROENTGEN IRRADIATION OF RABBIT'S EAR

(Small area treated)

Animal No.	Dosage in roentgens	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 90th Day Post-Treatment
2	1000	5% dorsal epilation....40d.	Recovery
2	1200	10% dorsal epilation....55d.	Recovery
1	1200	95% dorsal, 10% ventral epilation....48d.	50% dorsal, 10% ventral epilation
2	1500	95% epilation both surfaces....113d.	90% epilation both surfaces
2	1500	90% dorsal, 75% ventral epilation....43d.	10% dorsal, 50% ventral epilation
2	1500	75% dorsal, 85% ventral epilation....85d.	75% dorsal epilation
1	1750	100% epilation both surfaces....50d.	100% dorsal, 95% ventral epilation
2	2000	100% epilation both surfaces....35d.	100% epilation both surfaces
5	2000	100% epilation both surfaces....45d.	100% epilation both surfaces
5	2500	100% epilation both surfaces....32d.	100% epilation both surfaces
2	2500	100% epilation both surfaces....29d.	100% epilation both surfaces
4	3000	100% epilation both surfaces....38d.	100% epilation both surfaces
5	3000	100% epilation both surfaces....39d.	100% epilation both surfaces
5	4000	100% epilation both surfaces with ulcer....45d.	100% epilation both surfaces
4	4000	100% epilation both surfaces....36d.	100% epilation both surfaces
4	5000	100% epilation both surfaces....30d.	100% epilation both surfaces
5	5000	100% epilation both surfaces....39d.	100% epilation both surfaces

TABLE V

ROENTGEN IRRADIATION OF RABBIT'S EAR

(Large area treated)

Animal No.	Dosage in roentgens	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 90th Day Post-Treatment
16	1000	10% dorsal epilation....95d.	10% dorsal epilation
16	1500	75% dorsal epilation....95d.	75% dorsal epilation
10	2000	100% epilation both surfaces....23d.	100% epilation both surfaces
10	3000	100% epilation both surfaces with perforation....57d.	100% epilation both surfaces with perforation

TABLE VI

IRRADIATION OF RABBIT'S EAR BY RADIUM ELEMENT PACK

(Large area treated)

Animal No.	Dosage in mg-hr.	Tissue Reaction	
		Maximum Reaction and Time of Appearance in Days	Final Reaction at 90th Day Post-Treatment
15	15,000	90% epilation both surfaces....55d	50% dorsal, 95% ventral epilation
11	20,000	100% epilation both surfaces....38d	95% epilation both surfaces
6	24,000	100% epilation both surfaces....26d	100% epilation both surfaces
8	32,000	100% epilation both surfaces with ulcer....75d	Ear destroyed

day post-treatment, approximately 90 per cent of both surfaces of the ear was epilated, but by the ninetieth day there was a moderate return of hair to the dorsal surface. Doses of 20,000 and 24,000 mg-hr. gave early, complete epilation of both ear surfaces, while 32,000 mg-hr. produced destruction of the entire irradiated area.

The results of all experiments are summarized in Table VII. On account of the fairly large number of tests made on the mouse's tail, both with the radon bulb and roentgen rays, the results in this case are probably as reliable as may be expected in this type of work. The results of the experiments on rabbits' ears are only preliminary, since the number of tests made is too small. The gamma-ray and roentgen-ray doses given in this table *in pairs* are those which produce essentially equivalent reactions, within the limitations of the experiments.

Table VII

Epilation Dose	Radon bulb on the tails of young mice	Roentgen treatment of the tails of young mice
	400 mc-hr.	2350 r
Pathological Amputation	550 mc-hr.	2800 r
	Radon bulb on the rabbit's ear (small area)	Roentgen treatment of the rabbit's ear (small area)
Epilation Dose	250–300 mc-hr.	1650 r
Necrosing Dose	2700 mc-hr.	Unknown—over 5000 r
	Radium element pack on the rabbit's ear (large area)	Roentgen treatment of the rabbit's ear (large area)
Epilation Dose	15,000–20,000 mg-hr.	1500–2000 r
Necrosing Dose	24,000–32,000 mg-hr.	2000–3000 r

The experimental data enable us to calculate the gamma-ray emission of radium sources in terms of "equivalent" roentgens per minute, the equivalence being based on the relative effectiveness of roentgen rays and gamma rays in producing a given biological effect. Thus we have found that substantially the same degree of epilation is produced by 400 mc-hr. administered with the radon bulb at 1 cm. and 2350 r of roentgen radiation. Hence, so far as epilation of the mouse tail is concerned

400 mc-hr. at 1 cm. = 2350 r.

Since the gamma radiation of 1 mc. of radon is the same as that of 1 mg. of radium, we may express the exposures equally well in milligram-hours. Then 400 mg-hr. may be taken to correspond to 1000 mg., or 1 gram of radium applied for 0.4 hours, or 24 minutes. Therefore

$$1 \text{ gram Ra at } 1 \text{ cm.} = \frac{2350}{24} = 98 \text{ equivalent r per minute,}$$

or, in round figures, 100 equivalent r per minute.

Similarly, taking amputation of the mouse's tail as a basis of comparison, we have 550 mc-hr. at 1 cm. = 2800 r. Whence 1 gram Ra at 1 cm. = 85 equivalent r per minute. Making an approximate correction for the average distance of different parts of the tail to the source, the gamma-ray intensity at 1 cm. distance would be higher than the above, and in good agreement with the one for the epilation effect.

Since the radon bulb used in these ex-

periments is very small, it may be considered to be a point source. Therefore by applying the inverse square law it is possible to calculate the gamma-ray intensities at other distances from the source. At a distance of 6 cm. from 4 grams of radium, the intensity would be 11.1 equivalent r per minute. The radium pack, however, is not a point source. A correction for this brings the intensity for the pack at 6 cm. to approximately 10 equivalent r per minute. This value was checked indirectly by obtaining the ratio between the intensity at the periphery of our radon applicator and the intensity at 6 cm. from the pack, by means of *Drosophila* eggs and photographic films. This work was done by Dr. Henshaw and Mrs. Quimby respectively.

SUMMARY

1. We have described experiments in which mammalian tissues are used to compare the biological effectiveness of gamma rays and roentgen rays.

2. The tissues used are a segment of the tail of young mice, and the ears of an adult rabbit.

3. The biological changes studied varied from slight epilation to necrosis of the tissues.

4. In the experiments in which the mouse tails were employed, the large number of animals used permits a comparison between the effectiveness of gamma rays and roentgen rays on a fairly quantitative basis.

5. Since the roentgen-ray doses employed were measured in roentgens, it is possible to calculate the gamma-ray emission of radium in "equivalent" roentgens per minute. When the equivalence is based on the equality of effect produced in the mouse tails it is found that the gamma-ray emission of 1 gram of radium is approximately 100 equivalent roentgens per minute at 1 cm. distance. Translating this to the emission of the 4-gram radium pack at 6 cm., we find an emission of approximately 10 equivalent roentgens per minute.*

The writers wish to express their thanks to Dr. G. Failla and Mrs. Edith H. Quimby for their aid in the course of the experiments.

* For discussion see page 362.

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THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

V. COMPARISON BASED ON THE PRODUCTION OF ERYTHEMA IN HUMAN SKIN*

By JAMES J. DUFFY, ROBERT E. McNATTIN, MURRAY M. COPELAND, *and* EDITH H. QUIMBY

Memorial Hospital

NEW YORK CITY

FOR many years physicists have been devising instruments for the measurement of roentgen rays and radium rays, both as regards the intensity or quantity, and the quality. The many devices for the measurement and the diverse methods of expressing dosage multiplied until it was necessary to establish an international unit. This was established in 1928, and is known as the roentgen, or r. It is defined as follows: "The international unit is that quantity of X-radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in one cu. cm. of air at 0° C. and 760 mm. mercury pressure, such a degree of conductivity that one electrostatic unit of charge is measured at saturation current."

It is obvious that this definition is purely physical and therefore it does not take into consideration the response of living tissue treated under various conditions, such as intensity of radiation, time during which the full dose is administered, and the quality or the wave-length. To the radiologist this is of paramount importance. For instance, it is well known that the same quantity of roentgen rays measured in roentgens does not produce the same biological effect if the time during which it is administered varies from a few minutes to several days. On the other hand, very little is known about the influence of wave-length on the biological effect. Hence, one cannot determine the proper dosage for widely different qualities of radiation by physical measurements alone. By proper dosage we mean the dose which is therapeutically effective but is not unduly destructive to the normal tissues. In general, it is the effect on these normal structures which finally limits the amount of radiation which can be delivered to a deep-seated tumor from an external source. In particular, the effect on the skin is the most important because this structure usually receives the largest amount of the radiation. The skin is also the obvious indicator of the degree of the damage produced.

If physical measurements alone do not determine the dosage which the skin can tolerate, then it is necessary to find a biological method to estimate the output of any new source of radiation. Since the skin ultimately limits the dose delivered to a tumor, it is desirable to use this tissue as a biological indicator. The biological unit cannot be based on the tolerance of the skin to radiation, because in this case it is impossible to establish a definite end-point. There are all gradations of first and second degree reactions. The degree of reddening is of no value because the various amounts of pigmentation in the skin of different individuals make comparisons useless. No two observers can agree on the relative degrees of reaction. The inherent pigment of the skin also renders tintometers of doubtful value.

It is well known that the skin of different individuals shows a varying reaction to the same amount of radiation. For instance, there is a dose of radiation which produces no visible effect on the skin of the radio-

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

resistant person, but which will cause a slight to moderate reaction on the skin of a radiosensitive person. By utilizing this varying response to irradiation, the personal element in the observation can be eliminated almost entirely. It is necessary only to determine whether or not there is any visible effect following the exposure to a certain dosage of radiation. By repeated trials of varying amounts of radiation, it is possible to obtain any desired percentage of positive reactions. The dose which produces this percentage of positive reactions is the so-called "threshold erythema dose." The threshold erythema dose which we have adopted may be defined as that dose of radiation which will cause a perceptible change in the skin of 80 per cent of the subjects and no discernible discoloration in 20 per cent in two to four weeks after the exposure to the rays.

It should be noted that this dosage is not a therapeutic dosage, being about one-half the amount delivered to the skin of patients in our hospital. This dosage is simply a guide to the biological effects of the different types of radiation. Neither are these tests a measure of the quantity of the radiation delivered by the several sources, as measured by physical means. We are getting the biological effects and subsequently comparing the skin effect with the physical quantity.

The patients for these tests are chosen at random and the predetermined dose is given. Each patient is seen at weekly intervals for at least four weeks, and the presence or absence of reaction is noted. Each subject is seen by two observers, the decision as to whether or not there is any skin change is made independently and the questionable reactions are noted as negative reactions. The individual differences of the patients are eliminated by subjecting a number of patients of all ages and both sexes to these tests.

Although the results obtained are not mathematically exact, they are reasonably accurate for biological and clinical investigation.

In this series of tests, the extensor surface of the forearm was used for all irradiations. This field was chosen because the 700 kv. machine activates a horizontal tube. Thigh exposures, which were used in previous experiments, would have been unsatisfactory on account of the technical difficulty of properly setting and immobilizing the part in front of the port. Moreover, the exposure to the radium element pack is of such long duration that it was imperative to make the patient as comfortable as possible to prevent movement.

Three types of radiations were used in these experiments: radiations produced by 200 kv., by 700 kv., and gamma rays from the radium element pack.

The 200 kv. machine is a water-cooled outfit, running at 30 ma., and the target-skin distance is 50 cm. The rays are filtered by 0.5 mm. of copper and 3 mm. of aluminum. The size of the port was 8 × 8 cm. to conform approximately with the element pack aperture which cannot be altered.

The second source of radiation used in these tests was the General Electric 700 kv. machine. The current in this tube is 5 ma., and the rays are filtered by the equivalent of 5 mm. of copper. The port was 10 × 8 cm., at a target-skin distance of 60 cm.

The radium element pack was used as the third source of radiation. The factors of this source of radiation are as follows: it contains 4 grams of radium distributed over a circular area 7.5 cm. in diameter; the filter, partly platinum and partly brass, is equivalent to 2 mm. of lead. To decrease the time of exposure, the pack was applied at the shortest distance possible, that is, with the 6 cm. port. In order to lessen the secondary radiation from the filter and the sides of the port, a 3 mm. celluloid filter was interposed between the applicator and the skin. Therefore, the distance from the radium to the skin was 6.3 cm. The total dose was given without interruption, as were the doses with both roentgen machines.

Roentgen rays produced at 200 kv. were taken as the norm with which the other

types of rays were compared. The roentgen output was measured physically before each set of skin tests so that the error from daily fluctuation was avoided. The threshold dose for this radiation, determined in the manner outlined above, was found to be 450 roentgens, measured in air, or approximately 540 r allowing for back-scattering.

In making the tests with the 700 kv. radiation, the output of the machine was maintained constant at an arbitrarily established setting,* and a determination made of the time of exposure necessary for the radiation delivered at this rate to produce the threshold erythema. This time was found to be 55 minutes. If we now assume that a given number of roentgens will produce the same reaction independently of the quality of the radiation, we can determine the output of the 700 kv. machine by means of this erythema time. Since 540 r produce the erythema for 200 kv. roentgen rays, and it takes 55 minutes' exposure to cause the same reaction with 700 kv. roentgen rays, the latter are being delivered to the skin at the rate of $\frac{540}{55} = 9.8$ r per minute. Corrected for scattering, this is reduced to 8.6 r per minute. (The number of patients used in this series of tests was not large; after further experimentation it may be necessary to modify this result somewhat.)

Many subjects were tested with the radium pack. The threshold dose at the experimental distance of 6.3 cm. proved to be 14,100 mg-hr. When this is corrected to the standard distance of 6.0 cm., it is reduced by 10 per cent to 12,700 mg-hr.

With 4 grams of radium it takes 190 minutes to give 12,700 mg-hr. Comparing this with the effect of 540 r by roentgen rays at 200 kv., it is found that the equivalent roentgen output of the element pack at 6 cm. is 2.8 r per minute, as measured by this biological effect.

* This setting was different from that used in other experiments reported at this symposium. In Part VII all the results have been reduced to the same setting in order to facilitate the comparison.

The duration of time to produce a threshold erythema at the 10 and 15 cm. distances would be too great to subject patients to the ordeal, so the threshold erythemas at these distances are ascertained from physical experiments. At 10 cm. the threshold erythema dose is calculated to be 30,200 mg-hr., and at 15 cm., 63,500 mg-hr.

To deliver 30,200 mg-hr. of radiation it takes 7 hours and 33 minutes, or 453 minutes, hence the roentgen output at 10 cm. is 1.2 r per minute. The duration of time to deliver 63,500 r is 15 hours and 52 minutes, or 952 minutes. Therefore the output at this distance is 0.57 r per minute. These figures are obtained by calculation and are not derived from actual skin tests.

SUMMARY

1. The definition of the roentgen does not include any reference to the biological effect.

2. Normal structures finally limit the amount of external radiation that can be delivered to a tumor.

3. The skin is the first obvious indicator of the destructive process. It also serves as a biological indicator to the radiation therapist.

4. The threshold erythema is defined and its experimental determination is described.

5. Roentgen rays at 200 kv. produce a threshold erythema on the extensor surface of the forearm with 540 r, measured in air.

6. The rate of output of the 700 kv. machine as measured by this biological effect is 8.6 r per minute at a 50 cm. distance.

7. The 4-gram radium pack at 6 cm. has an output of 2.8 r per minute according to the erythema reaction test.

8. The calculated equivalent outputs of the pack for 10 cm. and 15 cm. distances are 1.2 and 0.57 r per minute, respectively.*

* For discussion see page 362.

THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

VI. COMPARISON BASED ON CLINICAL OBSERVATIONS*

By ROBERT F. McNATTIN
Research Fellow, Memorial Hospital
NEW YORK CITY

ACCORDING to our present knowledge, 200 kv., roentgen rays, 700 kv. roentgen rays, and gamma rays, belong to the same general class of ionizing radiations, and differ intrinsically only in wavelength. In consequence of this difference, they differ also in their penetrating power and any other property which is dependent on the wave length. The biological properties of ordinary roentgen rays and gamma rays have been discussed for many years by many investigators, but there is at present no unanimity of opinion. Some claim that roentgen rays and gamma rays have the same biological properties, while others attribute to gamma rays a more selective action, making this quality of radiation more effective in the treatment of certain neoplastic diseases.

The absence of a generally accepted conclusion on this point after years of clinical and laboratory experimentation bespeaks the difficulties of the problem. The chief difficulty results from the fact that roentgen rays and gamma rays cannot be used under the same conditions. With the amounts of radium ordinarily available for external treatments—up to 4 or 5 grams—it is necessary to keep the radium-skin distance within 15 cm., otherwise too long a time is required to deliver a therapeutic dose. High voltage roentgen rays, on the other hand, are applied with a target-skin distance of 50 cm. or more. Since the intensity of radiation delivered to a given tissue depth depends markedly on the distance between the source and the skin surface, it is evident that, on this score alone, roentgen and radium treatments as ordinarily given are not strictly comparable. There is, in addition, another point of difference which recent experience has shown to be very important. It is the time during which the total dose of radiation is administered, and the intervals at which individual treatments are given. With radium packs at 10 or 15 cm. distances, the complete cycle of treatment is apt to extend over a considerably longer time than is found expedient in the case of roentgen therapy.

In addition to these "physical" limitations, which could be overcome by a suitable increase in the amount of radium, there are the well-known difficulties which apply to all statistical comparisons in cancer therapy. In order to make the proper comparison, patients having a certain type of tumor in a given location should be taken at random to be treated with one of the three qualities of radiation. For instance, the first patient admitted for treatment might be given 200 kv. roentgen rays, the second, 700 kv. roentgen rays, the third gamma rays, the fourth, 200 kv. roentgen rays, and so on in rotation without subjective selection. With a large number of patients in each group, inequalities in the clinical factors of the individual cases would tend to balance out. Then by keeping complete records of all the patients over a sufficiently long period of time, it would be possible to make comparisons under different classifications, such as: immediate effects, local effects, general effects, temporary regression, recurrence, metastasis, etc. In this way one could decide eventually by which radiation the best results are ob-

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

tained, at least under the conditions in which the three qualities of radiation were applied.

The practical application of such a procedure is fraught with numerous difficulties. Patients cannot be treated like laboratory animals. Adjustments must be made to meet the requirements of the individual case for the best interests of the patient. Certain predilections, preferences, and idiosyncracies of both patient and physician in charge of the case cannot be ignored. The number of patients applying for treatment and the waiting lists for the three types of treatment, in conjunction with the urgency of treatment, have no small influence on the decision reached.

At the Memorial Hospital 200 kv. roentgen rays have been used since 1920, radon packs of 1000 to 3000 mc. since 1915, a pack with 4 grams of radium since 1925, and 700 kv. roentgen rays since October, 1931. A very large number of patients have been treated and reasonably complete records have been kept, but nevertheless it is not simple to make a comparison of the relative merits of the three qualities of radiation. The stringent conditions set forth above for a proper comparison have not been met on account of practical difficulties, some of which have already been mentioned. In the case of 700 kv. roentgen rays, of course, the time is entirely too short for the evaluation of clinical results. Furthermore, on account of the necessity of physical and biological experimentation to establish equivalence of dosage, and some interruptions due to mechanical difficulties which are always present in a new type of apparatus, the number of cases of any one type which have been treated with 700 kv. roentgen rays is too small for statistical purposes. Accordingly the present report is far from satisfactory in several respects. Nevertheless, while the data cannot be considered as strictly objective, they are at least sufficient to formulate certain definite impressions. These impressions are not only those of the writer, who has been in intimate contact with the work for a relatively short time, but they represent also the combined experience of those members of the hospital staff who have followed closely the radiation treatment of the type of case discussed here. In spite of its limitation, therefore, this preliminary report is added to the other papers of this symposium. The lack of any definite information on the subject and the general interest of radiation therapists in the use of higher voltage roentgen rays are perhaps sufficient justification for making any report at this time.

In view of the experimental results obtained at the hospital, which have been presented in the preceding papers, it is evident that the significant point to be determined by clinical observation is the relative effect produced on the skin and in tumors by the three qualities of radiation. The effect produced on the skin can be followed easily from its inception to the end. But the effect produced on a tumor is difficult to evaluate, particularly when the tumor is deep-seated or otherwise inaccessible. For this reason it was decided to base the comparison on cases of cancer of the larynx, pharynx, hypopharynx, and tonsil. Tumors in these locations, while deep-seated in the sense that radiation applied externally must first traverse the skin and other tissues, are nevertheless observable at all times. Their course after irradiation, therefore, can be followed closely. The effect on the mucous membrane can also be observed. Furthermore, these tumors are amenable to treatment by external irradiation in fractional doses, as shown by Coutard. Many patients had been treated in this way at the hospital with the radium pack or with 200 kv. roentgen rays before the 700 kv. tube was installed. Accordingly, it was also the simplest procedure to use the new quality of radiation in an analogous way. The time interval during which the complete treatment was administered was about three weeks, to correspond with treatments given with 200 kv. roentgen rays. The radium pack cases which are reported here were treated previously, with

no definite idea in mind of a direct comparison, and therefore the time factor was not kept within pre-established limits.

In view of the short time during which the 700 kv. radiation has been used, we shall confine our attention to the immediate effects noted during, and for a short period following, the administration of radiation. By "immediate effects" are meant the changes in the skin, mucous membrane, and tumor, as well as the constitutional effects.

The first group of cases to be considered consists of those treated with the 200 kv. (peak) roentgen machines, of which there are two types. The air-cooled machine operates at 4 ma., and the water-cooled one at 30 ma. A filter of 0.5 mm. of copper and 3 mm. of aluminum is used, with target-skin distances of 50 or 60 cm. The irradiated field is about 8 × 10 cm.

The method of application is similar to that advocated by Coutard of the Radium Institute in Paris. This type of treatment has been used for nearly two years at the Memorial Hospital, but has been modified during the past year. At first a daily dose of 400 r, measured in air,* was applied to alternate sides of the neck in treating lesions of the larynx, pharynx, nasopharynx, or tonsil, until a total of 4800 r had been given. This required a period of treatment of thirteen to fourteen days. In all of these patients the sequence of symptoms was as follows: After four to six treatments had been administered, a mucositis began to develop, and the skin of the neck began to show some redness and beginning desquamation. Seven days following the completion of the treatments, there was a very sharp mucositis, as represented by a thick, diphtheritic membrane covering the mucosa of the area treated. By this time many vesicles and small fissures had appeared in the skin over the areas treated. By the tenth day there was an epidermicidal reaction of the skin, consisting of more or less marked blistering. The mucositis had reached its height; there was considerable edema of the surrounding tissues and all the visible structures were covered with a diphtheritic membrane. This reaction was present for several days. In some cases it did not appear as soon as in others, but in all cases the radiation reaction reached its height not later than twelve to sixteen days after the treatments were completed. Six to eight weeks later the major portion of this reaction had subsided, and the skin was completely healed.

During this period the patients developed difficulty in swallowing, loss of taste, loss of appetite, and complained of a severe burning sensation in the throat. Because of these symptoms, they frequently suffered marked loss of weight. Efforts were made to maintain the caloric intake by means of frequent feedings. Occasionally it was necessary to institute nasal tube feedings, and in a few cases to perform a gastrostomy. Sometimes it was necessary to hospitalize a patient because of inadequate nursing care at home. Most of the patients had symptoms of severe pain radiating to both ears, and some of them developed such difficulty in breathing that a tracheotomy was required.

Because of the severity of the reaction following this type of treatment, the course of therapy has been altered so that for some time we have been giving smaller daily doses—250 to 300 r—over a longer period of time, namely, twenty-one to twenty-three days. We are now giving in most cases a greater total dosage than that administered when 400 r was given daily to alternate fields. We learned that when the period of treatment in days was increased and the daily dose lowered, a satisfactory radiation effect was not obtained unless the total amount given was increased by at least 25 per cent, thus bringing the total dose, as a rule, to 6000 r.

Calculations have been made in the Physics Department to determine approximately the tissue doses delivered to the average patient under these conditions.

* All doses of roentgen rays which are expressed in roentgens in this paper refer to measurements made in air, without back-scattering.

For this purpose the following factors were taken: Average depth of tumor below the skin, 4 cm.; average distance to the skin on the opposite side of the neck, 8 cm.*; average back-scattering, 25 per cent; threshold erythema dose for fields of comparable size, 400 r measured in air, or 600 r on the skin, *administered at one time*. The calculated average tissue doses on this basis are: On the skin of either side of the neck, 8 threshold erythema doses (T.E.D.); in the tumor, 6 T.E.D. (administered within about three weeks).

With this type of treatment, the skin reactions are not so severe as when the treatment is completed in about two weeks, although the mucositis is just as sharp as that obtained by larger daily doses. The effect on the primary lesion has been equally good with both methods. The constitutional effect on the patient who has received the smaller daily dose is less. All the symptoms are present, namely, dysphagia, loss of taste, loss of appetite, and sometimes difficulty in breathing, but they are much less severe, so that the care of the patient is not so difficult. There is, however, individual variation, so that one may have to hospitalize the patient for adequate nursing care, even when the smaller daily dose is given.

With the 700 kv. machine the physical factors are: 700 kv. peak, 5 ma., a filter equivalent to 5 mm. of copper, and a target-skin distance of 60 to 65 cm. The irradiated field is about 9 cm. in diameter. Since we were using a type of roentgen radiation with which we had no previous clinical experience, it was necessary to proceed cautiously. The threshold skin erythema dose was first determined, starting with a dose which had been determined by physical measurements to be perfectly safe. Once this was established, the dose was gradually increased until the practical upper limit of skin tolerance was determined when a single massive dose was applied.

A large group of mixed cases was treated during the first few months, namely, osteogenic sarcoma, carcinoma of lung, breast, stomach, and rectum. In general the treatments were administered fractionally in cycles, giving various doses. A great deal of time was consumed in this procedure, but simultaneously biophysical experiments were being carried out. It was not until March, 1932, after it was determined what could be expected, that we began treating cases of carcinoma of the larynx, pharynx, hypopharynx, and tonsil, using the divided dose technique similar to that used with the 200 kv. machine.

It will be recalled that the dosage used with 200 kv. roentgen rays was 250 to 300 r daily on alternate sides of the neck. This corresponds to a skin dosage of approximately $\frac{1}{2}$ to $\frac{2}{3}$ *threshold* erythema unit, without allowing for cross-firing. With 700 kv. a more conservative procedure was adopted and the daily treatments were limited to $\frac{1}{4}$ to $\frac{1}{2}$ T.E.D. The average total dose for the skin of the neck, making allowances for back-scattering and cross radiation, has been 5.3 T.E.D. The average total tumor dose has been 4.7 T.E.D. It will be noted, therefore, that both the skin and tumor doses given with 700 kv. roentgen rays are considerably smaller than those given with 200 kv. roentgen rays, under very similar conditions.

The course of the reaction, as a rule, was as follows: After about the twelfth treatment the skin began to show slight reddening and a slight mucositis had developed. At the end of the treatment these symptoms had increased somewhat. One week after the last irradiation there was a very sharp mucositis and marked regression of tumors. In general, the skin showed only superficial desquamation. During and following the treatment, the patients complained of a moderate amount of dryness in the throat. Those with laryngeal lesions complained of some difficulty in swallowing. The general condition of the patients remained good.

While no definite conclusions can be drawn as to the final results obtainable in

* The two cross-fire beams used were not from opposite directions, but pointed partly toward the back of the neck.

this group of cases with 700 kv. roentgen rays and the divided dose technique, the present indications are that at least the same results can be obtained using a dosage which causes considerably less discomfort to the patient locally and generally.

In those cases treated by the radium element pack, the plan of treatment varied with the exigencies of the case, the availability of the radium, and the judgment of the physician in charge of the case. Because of these conditions, a direct comparison is rendered still more difficult.

The element pack consists of 4 grams of radium so mounted in a lead and brass case that it may be applied through two ports, both of which are 10 cm. in diameter. In one the radium-skin distance is 6 cm., in the other, 10 cm. It has also been used with a radium-skin distance of 15 cm. The beam of radiation is filtered by an equivalent of a 2 mm. of lead. The total doses given with the pack have ranged from 48,000 milligram-hours to 200,000 mg-hr. This, however, does not give the proper idea of the tissue doses employed. In order to do this, the cases have been divided into three groups according to the radium-skin distance at which they were treated. In the 6 cm. group, the average skin dose was 4.3 T.E.D. and the average tumor dose 2.2 T.E.D. In the 10 cm. group, the average skin dose was 2.8 T.E.D., and the average tumor dose 1.7 T.E.D. In the 15 cm. group, the average skin and tumor doses were respectively 2.3 and 1.6 T.E.D. Thus it will be seen that, while the milligram-hour doses in the 15 cm. group reached a maximum of 200,000 mg-hr., the tissue doses were actually lower than for the other two groups. It will be noted also that when tissue doses are expressed in terms of the threshold erythema unit experimentally established according to the method described in the preceding paper in this symposium, the cases treated with the radium pack received much less radiation than those treated with 200 kv. or 700 kv. roentgen rays. Nevertheless, the cases treated at the longer distances have shown results comparable to those obtained with much larger roentgen doses.

The patients treated at the 10 or 15 cm. distance reacted in this fashion: About twelve to sixteen days after the treatment was started, the patients usually complained of dryness of the throat. About the twentieth day they began to complain of slight difficulty in swallowing, the skin showed some reddening, and mucositis was beginning to develop. A few days after the treatments were completed, a very sharp mucositis was present. At this time the skin began to blister and to become fissured. The patient complained frequently of dysphagia, and occasionally of dyspnea. A few patients required hospitalization.

When the reaction had reached its height, fourteen to eighteen days following the treatment, the skin directly over the portal developed a severe epidermicidal reaction, with blistering and denudation of the superficial layers. There was a very sharp mucositis. As in the cases treated with roentgen rays, often fluids had to be given by means of a nasal tube, combined with other general supportive treatments. The reaction reached its peak and began to subside six to eight weeks after the treatment was completed. The reaction involving the skin and mucous membrane had subsided entirely by the end of the twelfth week. Thus it was found that the use of the element pack, giving divided doses of radiation to the same field on alternate days, of the amounts stated above, results in a severe reaction, which, in general, however, is not quite so severe as that caused by the heavy dosage of 200 kv. roentgen rays described above.

One interesting observation was made in the cases treated with the radium pack, i.e., that when the skin had healed, it became soft and pliable, and there was no induration of the underlying tissues. In those cases treated with large doses of 200 kv. roentgen rays, who had a reaction equivalent to that produced by the radium pack, the skin was hard and brawny, and the underlying tissues were quite indur-

ated. This important point of difference may be explained by the marked difference in skin dosage administered with the pack and with 200 kv. roentgen rays. The average skin doses were 2.3, 2.8, and 4.3 T.E.D. with the radium at the 15, 10, and 6 cm. distances respectively. With the 200 kv. roentgen rays the average skin dose was 8 T.E.D. But on this basis it is difficult to account for the sharp "immediate" skin reaction produced by the radium pack. It should be remembered, however, that it is not a simple matter to evaluate the degree of severity of a skin reaction.

In conclusion, we may summarize our clinical observations as follows:

1. Therapeutic doses of comparable effectiveness may be administered to tumors of the upper respiratory tract by the divided dose method, using 200 kv. roentgen rays, 700 kv. roentgen rays, or gamma rays of radium.

2. A survey of such cases treated at the Memorial Hospital with each of the three qualities of radiation indicates that the tumor doses which, *as a first approximation*, may be considered to be therapeutically equivalent, are: for 200 kv. roentgen rays, 6 T.E.D.; for 700 kv. roentgen rays, 4.7 T.E.D.; for gamma rays, 1.6 to 2.2 T.E.D., each administered fractionally over a period of three weeks (or even longer in the case of gamma rays). The threshold erythema unit used here is equivalent to 600 r of 200 kv. roentgen rays filtered by 0.5 mm. of copper and 3 mm. of aluminum, including back-scattering, and administered at one time.

3. When the above tumor doses are administered, the skin reaction is very marked in the case of 200 kv. roentgen rays, also very marked with gamma rays, and, thus far, the least severe in the cases treated with 700 kv. roentgen rays. On the other hand, after the skin has healed, the mildest subsequent changes are found in the cases treated with gamma rays. (Cases treated with 700 kv. roentgen rays have been too recent for such a comparison.)

4. The constitutional effects have been relatively mild in cases treated with 700 kv. roentgen rays, and about equally severe in all cases treated with 200 kv. roentgen rays and those treated with the radium pack.*

* For discussion see page 362.

THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

VII. CORRELATION OF EXPERIMENTAL RESULTS*

By G. FAILLA, D.Sc.
Biophysical Laboratory, Memorial Hospital
NEW YORK CITY

EVER since roentgen rays were found to be useful in cancer therapy, there has been a trend toward the use of higher voltages, especially for the treatment of deep-seated tumors. Manufacturers have kept pace with the demand for higher voltages, but at each step the price and size of the machine have also increased. Since the 200 kv. voltage value was reached, about twelve years ago, there has been a tendency to regard this as the practical limit beyond which it would be hardly profitable to go. Theoretical considerations and physical experiments indicate, in fact, that the gain in the amount of radiation reaching the deeper layers of tissue in the human body increases slowly with the tube voltage (and filtration). If the voltage is not too low, the same gain can be obtained by increasing the target-skin distance, without the complications attendant upon the use of higher voltages (thicker filters, or both). Accordingly, most radiologists in this country have adopted a tube voltage of 200 kv., a filter of 0.5 mm. copper, and a target-skin distance of 50 cm., as more or less standard factors for "deep therapy."

In recent years, however, some radiologists have used filters of 1 to 2.5 mm. of copper with voltages of 180 to 200 kv., and have claimed markedly better clinical results. The inference that this improvement was brought about by the increase in the filter, however, is not quite justified. At the same time that the filter was increased, the time factor of the treatment was also materially altered, either intentionally or for practical reasons. In fact, in most instances, it was completely changed by administering daily fractional doses over a period of weeks, instead of one or a few large doses. Nevertheless, the thesis of the greater therapeutic efficacy of highly filtered roentgen rays (200 kv. and 2 mm. Cu) has gained considerable support.

Evidence tending to corroborate this conclusion from a different angle has been adduced by radiologists who have used large radium "packs." Among these there seems to be a unanimity of opinion to the effect that better clinical results are obtained with radium packs than with 200 kv. roentgen rays. While this conclusion is really based on clinical impressions rather than on a strict comparison under rigid conditions, it cannot be dismissed lightly. Radium packs as ordinarily used (about 10 cm. radium-skin distance) deliver depth doses which are considerably lower than those obtainable with 200 kv. roentgen rays. (See Part 1 of this symposium.) Therefore, if the clinical results obtained with the pack are better than, or even equal to, those produced by 200 kv. roentgen rays, there must be some intrinsic superiority in gamma rays.

These considerations make it very desirable to carry out a test under comparable conditions. Since the amount of radium required for this purpose would be too expensive, it is preferable to develop a roentgen tube and generator to operate at some voltage approaching that at which gamma rays could be produced artificially. With this idea in mind, Dr. W. D. Coolidge developed an apparatus which is capable of operating at 900 kv. (peak) with a current sufficient to give a high intensity of radia-

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932

tion at 50 cm. from the target. Through the kindness of the General Electric Company this apparatus was installed at the Memorial Hospital in July, 1931. The tube has been used regularly at 700 kv. and 5 ma. for clinical and experimental work.

Even before this new source of penetrating radiation was made available, the problem of the relative biological effectiveness of roentgen rays and gamma rays had been attacked in our laboratory from several different aspects. In fact, the proper conditions for experiments of this sort had been formulated by us some years ago.[2,3] The reasoning involved is as follows: In the first place, the point in question is not whether equal amounts of roentgen rays and gamma rays produce the same biological effects, because this is immaterial. Furthermore, this approach to the problem introduces very serious complications, because one must decide first how "equal amounts" of roentgen rays and gamma rays should be measured. The all important point is whether the *relative* radiosensitivity of any two living tissues is the same when roentgen rays or gamma rays are used. In other words, if tissue A is four times as sensitive to roentgen rays as tissue B, is tissue A also four times as sensitive to gamma rays as tissue B? In order to determine this point experimentally it is not necessary to measure either roentgen rays or gamma rays, except so far as constancy of radiation output is concerned. For the latter purpose, it is not necessary to measure both qualities of radiation with the same instrument, or even by the same method. (In the case of radium, no measurement of the radiation is really necessary.)

The determination of the radiosensitivity of a tissue is, of course, very important in making any such comparison. It involves in some way the measurement or the estimation of the degree of biological effect, which is a very difficult thing to do at best. But this may be simplified very materially by choosing the proper "endpoint" and the proper criterion for establishing it. To begin with, we may define the radiosensitivity of a tissue by the amount of radiation required to produce a certain effect—the larger the dose required to produce this effect, the less radiosensitive the tissue. For this purpose the "dose" can be expressed simply in terms of the duration of the exposure to a source of radiation of constant output. For the comparison which we are considering here, the "effect" need not be the same in the two tissues or test objects. The essential condition is that the same effect be produced in the same time by both qualities of radiation, e.g., roentgen rays and gamma rays. Thus we may choose human skin as one tissue and threshold erythema as the effect produced in this tissue. As a second tissue or test object we may take *Drosophila* eggs, and 50 per cent survival as the endpoint. The test now consists in determining the exposures to the source of roentgen rays and gamma rays which produce, respectively, the threshold erythema on the human skin and 50 per cent survival in a large group of *Drosophila* eggs.

Such tests have been made in our laboratory, and they have been described in the preceding papers in this symposium. It has been found that, with a given roentgen-ray intensity (and other specified experimental conditions) an exposure of 50 minutes produces the threshold erythema, and an exposure of 39 minutes produces 50 per cent survival of *Drosophila* eggs. In spite of the difference in the nature of the effects considered, we may agree to say that *Drosophila* eggs are approximately $\frac{50}{39} = 1.3$ times more sensitive to roentgen rays than human skin, under the conditions in which the tests were made. The results of parallel experiments carried out with gamma rays are: 190 minutes' exposure to produce the threshold erythema and 31 minutes' exposure to produce 50 per cent survival of the eggs. Therefore, in this case, *Drosophila* eggs may be said to be about 6 times $\left(\frac{190}{31} = 6.1\right)$ more sensitive than

human skin. According to these results the relative radiosensitivity of human skin and *Drosophila* eggs is quite different for roentgen rays and gamma rays. For the present we need not discuss the significance of this finding. By this concrete example we wish to illustrate the general method of attack, indicating in particular how the final result may be obtained without the necessity of physical measurements of dosage.

That the information obtained by following the experimental plan outlined above is what is needed to decide the question of the relative therapeutic efficacy of roentgen rays and gamma rays is evident from the following considerations. In cancer therapy the chief difficulty is encountered in the treatment of deep-seated tumors. In such cases the treatment of the tumor by roentgen rays or radium packs necessitates the irradiation of normal tissues as well. Accordingly the relative radiosensitivity of tumor and normal tissues is really the controlling factor which determines whether the treatment by external irradiation will be successful or not. If the tumor is much more resistant than the surrounding normal tissues, it is impossible to destroy it (by external irradiation) without seriously damaging some normal tissues. Tumors which are more sensitive than the surrounding normal tissues may be treated successfully, at least theoretically. If now the relative radiosensitivity of tumor and normal tissues is different for roentgen rays and gamma rays, then one of these qualities of radiation is therapeutically more effective for treating the tumor under consideration. For instance, if a tumor should react to roentgen rays and gamma rays in the same way that *Drosophila* eggs do in the example given above, gamma rays would be much to be preferred for the treatment of such a tumor. It will be recalled that *Drosophila* eggs were found to be 6 times more sensitive than the human skin when both were irradiated with gamma rays, whereas in the case of roentgen rays they were only 1.3 times more sensitive.

In order to obtain information of this sort, of direct practical application, it would be necessary to determine the radiosensitivity of many types of tumor, in different locations, and many normal tissues, under the conditions which obtain in radiation therapy. While this is not impossible, it is a very difficult problem which will require many years of painstaking clinical and laboratory work. For this reason it is important to determine first of all whether there is any well-founded basis for supposing that the relative radiosensitivity of any two tissues is or is not different for roentgen rays and gamma rays. Essentially the problem is to determine the influence, if any, of wave-length *per se* on the radiosensitivity ratio for any two tissues.

Certain well-established physical phenomena lead to the conclusion that the radiosensitivity ratio should be independent of the wave-length, and therefore most physicists are of this opinion. On the other hand, there are also some known facts which at least make possible the existence of a wave-length effect on the radiosensitivity ratio. Furthermore, our knowledge of the interaction between radiation and matter—especially living matter—is by no means sufficiently complete to enable us to settle the question by *a priori* reasoning. Hence it is necessary to investigate the problem experimentally.

Since the point under consideration is whether or not the wave-length influences the radiosensitivity ratio in general, it is evident that negative experimental results do not furnish the proper answer. That is, if the sensitivity ratio for two given tissues is found to be independent of the wave-length, it does not necessarily follow that such would be the case for *any* other two tissues. It is to be expected that for some tissues the sensitivity ratio will be independent of the wave-length. On the other hand, if an unequivocal wave-length dependence is found experimentally in the case of two given tissues, it will be definitely established that the dependence of

the sensitivity ratio on wave-length, *in general*, is not only possible but probable. It is evident that in either case the experimental test must be made with as many pairs of tissues or test objects as are found suitable for such quantitative studies. For this reason, the work in our laboratory has been carried out with several biological test objects. In addition, several chemical and physical test objects have been used in the hope that the information thus obtained might be useful in the interpretation of the biological findings. With these ideas in mind we shall now attempt to correlate all the experimental data obtained so far.

Obviously the correlation might be made in many different ways. We have selected one mode of approach which, while somewhat indirect, serves to emphasize certain practical considerations. It is as follows: Suppose that we have had available for many years roentgen rays produced at 165 to 200 kv. and that we have studied certain physical, chemical, biological, and therapeutic effects, which they are capable of producing. We then acquire an apparatus which generates roentgen rays at 700 kv., and 4 grams of radium in a "pack." We wish to use these new sources of radiation for the treatment of patients, and we wish to avoid or shorten the long period of empirical clinical experimentation which was necessary with the first source of roentgen rays at our disposal.

Possessing an ionization instrument which can be calibrated in roentgens with 200 kv. roentgen rays, we naturally use this to determine the intensity of the 700 kv. roentgen beam and of the radium pack radiation. We find that, under the normal operating conditions of the high voltage tube, the intensity of radiation thus measured is 25 r per minute at 50 cm. from the target. Similarly, for the pack we find that the gamma-ray intensity is 9.5 r per minute at 6 cm. from the radiating surface. These measurements having been made with a small spherical celluloid chamber (referred to as "H" in Part I, q.v.) we decide to repeat the measurements using a comparable aluminum chamber ("B" of Part I) also calibrated in roentgens with 200 kv. roentgen rays. We now find that the same two beams of 700 kv. roentgen rays and gamma rays appear to have, respectively, intensities of 10 r per minute at 50 cm. and 2.9 r per minute at 6 cm. Accordingly we find that the intensity of gamma rays at 6 cm. from the radium is $\left(\frac{9.5}{2.9} = \right)$ 3.3 times larger when measured with the celluloid chamber than it is when measured with the aluminum chamber. Obviously the conclusion is that the calibration in roentgens with 200 kv. roentgen rays does not hold for gamma rays or 700 kv. roentgen rays in the case of one of the chambers or in the case of both. For the present, at least, it is preferable not to assume that the celluloid chamber can be used to measure gamma rays in roentgens.* (The aluminum chamber is, of course, out of the question.) Accordingly we cannot say that we have measured the intensity of our 700 kv. roentgen beam and the radium pack emission in *roentgens* per minute. But for our present purposes we may use the expression *equivalent* roentgens per minute, always bearing in mind the basis on which the equivalence was established.

Proceeding further with our hypothetical mode of approach, we decide to test the new sources of radiation by a chemical method. Experiments in which Eder's solution was exposed to 200 kv. roentgen rays under certain definite conditions have shown that the precipitation of 1 mg. of mercury (in the form of mercurous chloride) per 5 c.c. of solution requires 330 r of radiation (see Part II). Since both 700 kv. roentgen rays and gamma rays are capable of producing the same chemical change, it is possible to calibrate by this reaction the "new" sources of radiation in *equivalent* roentgens per minute—the equivalence in this case being based on the relative ability of 200 kv., and 700 kv. roentgen rays, and gamma rays to precipitate mercurous chlo-

* There is indirect evidence which might warrant this assumption.[5,6]

ride out of Eder's solution under specified conditions. The results of such determinations are 15.7 equivalent r per minute for the 700 kv. roentgen source at 50 cm. and 4.6 equivalent r per minute for the radium pack at 6 cm. distance. As one might well expect in view of the materials used, the results obtained so far are not in good agreement.

After all, the avowed aim of our experiments with the new sources of radiation is to calibrate them for therapeutic use. Therapeutic effects are brought about by biological reactions. Therefore we decided to make our tests with living materials. Having heard a great deal about the use of *Drosophila* eggs for calibration purposes, as advocated by Dr. Francis Carter Wood, we decided to make the next tests with this material. By such experiments (as described in Part III) we find that the equivalent roentgens per minute of the 700 kv. roentgen source at 50 cm. and the radium pack at 6 cm., are 29 and 15 respectively. But, being somewhat skeptical of broad generalizations based on long range extrapolations, we conclude that it is necessary after all, to calibrate the new sources of radiation by the skin erythema reaction. The results of these tests (described in Part V) give 17 equivalent r per minute at 50 cm. for the 700 kv. roentgen source, and 2.8 equivalent r per minute for the radium pack at 6 cm. These figures are entirely different from those obtained with *Drosophila* eggs.

Without pursuing further this mode of presentation, we give in Table I the results of all the tests made so far, and we shall attempt to bring out their significance. The values obtained by exposing photographic films with and without intensifying screens are apt to be influenced by a number of extraneous causes, due principally to the long distances from the radiating sources at which the determinations had to be made. Accordingly they may not represent very closely the equivalent intensities of the two beams of radiation at the distances which have been taken as standard, and at which most of the tests were made. For this reason, these figures have been enclosed in parentheses. They have no very direct bearing on the problem under discussion. However, they bring out an important point which must be borne in mind when the photographic method is used to determine the exposure of radium or roentgen-ray workers. It will be seen from the table that films calibrated by ordinary high voltage roentgen rays give an indication of the intensity of gamma rays, which is about one-tenth of that measured by a celluloid ionization chamber. If intensifying screens are used, the discrepancy is about 50 fold.

The results of the biological tests made with wheat seedlings, *Drosophila* eggs, and mouse tails, are not very discordant among themselves. Consequently the radiosensitivity ratios for these biological materials, as used in our experiments, do not vary greatly when the quality of radiation is changed from that of ordinary roentgen rays to that of gamma rays. While the differences (ranging from 10 to 40 per cent) may be significant, or at least indicative, we shall assume for the present that they are not. Accordingly we may conclude that the dependence of the radiosensitivity ratio on wave-length is not definitely established by these experiments. Similarly we may conclude that, on the whole, there is a fairly close connection between ionization, as measured by the celluloid chamber, and certain biological effects produced in these three test objects. But this does not permit us to make the generalization that there must also be the same relation between ionization and all biological effects produced in all living materials. Because, if this conclusion is correct, then the production of erythema on the human skin should bear the same relation to ionization in a celluloid chamber. Our skin erythema tests have shown definitely that this is not the case.

Now, we realize that "erythema" is anathema to many radiologists, and that the general belief is that no "accurate"

determinations can be made by using this as a biological indicator. Naturally a great deal depends on what degree of accuracy is demanded, and on the method of investigation adopted. During the last twelve years we have made literally thousands of skin tests with radium and roentgen rays, and we have developed a method which, while very laborious, gives consistent and reproducible results. (This is described in Part V and several previous publications.) If a reasonably large number of patients is used for the tests, the results are reliable within ±10 per cent. But from the figures of Table I it will be seen that the discrepancy between the ionization measurements and the erythema determinations with the radium pack is $\left(100 \times \frac{9.5}{2.8} = \right)$ 340 per cent. Hence, even assuming that our erythema values are in error by 50 per cent, it is not possible to obtain an agreement between ionization in the celluloid chamber and erythema reaction over the range of wave-lengths covered by 200 kv. roentgen rays and gamma rays. The figures in the table are based on 500 to 550 r (including back-scattering) as the amount of filtered 200 kv. roentgen radiation required to produce the threshold erythema on the forearm of the average patient; and on 12,000 to 13,000 mg-hr. administered to the same region with a radium-skin distance of 6 cm. It will be conceded by all those who have had experience with these two types of radiation that the above figures are substantially correct.

Nor can the 340 per cent discrepancy be attributed to the difference in the duration of irradiation when roentgen rays and

TABLE I

RADIATION OUTPUTS OF THE 700 KV. ROENTGEN TUBE AT 50 CM. AND THE RADIUM PACK AT 6 CM. EXPRESSED IN "EQUIVALENT" ROENTGENS PER MINUTE, BASED ON DIFFERENT EFFECTS

Test Object	Material	Effect	700 kv., 5 mm. Cu, Half-Value Layer—1.1 mm. Pb	Gamma Rays 2 mm. Pb, Half-Value Layer —8.2 mm. Pb.
			Equivalent r/min.	Equivalent r/min.
Spherical ionization chamber, 1.52 cm. diameter	Celluloid 0.2 mm. thick	Ionization	25	9.5
	Aluminum	Ionization	10	2.9
Eder's solution		Ppt. HgCl	15.7	4.6
Iodides in acid solution, 10% KI in 0.05 N H_2SO_4		Liberation iodine	7.5–10 8.5	2.3–3.4 3.3
Photographic film alone		Darkening	(4)	(1)
Film with intensifying screens		Darkening	(5)	(0.2)
Wheat seedlings		Reduction of linear growth	29	11.4
Drosophila eggs		Killing	29	15
Mouse tails		Amputation, epilation		10 9
Human skin		Erythema	17	2.8

Nor can the 340 per cent discrepancy be attributed to the difference in the duration of irradiation when roentgen rays and

gamma rays are used. Preliminary tests made several years ago indicated that the dose of roentgen rays required to produce the threshold erythema is substantially the same whether the time of administration is ten to twelve minutes, or one hour. (These tests would have detected differences greater than 20 per cent.) The longest irradiation used in the skin tests with the radium pack was a little over three hours, so that it is difficult to see how the time factor could possibly introduce an error of 340 per cent. The time factor is not involved at all in the experiments made with wheat seedlings and *Drosophila* eggs because the intensities of the three qualities of radiation were purposely adjusted to give the same biological effect in very nearly the same time of exposure.

It is contended by Wood, and others, that skin erythema is the integrated result of a great many complex biological reactions. Furthermore, when a part of the human body is irradiated, the scattering of radiation by the tissues introduces additional complications. All this is perfectly true, but it in no way *explains* the discrepancy between the *Drosophila* egg experiments and the skin erythema determinations, as the following analysis will show. Packard's very careful experiments in which *Drosophila* eggs have been irradiated "in air" with roentgen rays of different wave-lengths, show that there is a direct relation between air ionization and the lethal effect of roentgen rays on the eggs, irrespective of the wave-length, within wide limits.[8] This result *per se* is of no importance at all, because no one is particularly interested in killing flies with roentgen rays, and the calibration of roentgen machines can be made much more readily by the use of ionization instruments. Packard's experiment, however, assumes very great importance if the results are to be interpreted to mean that the wave-length independence found for *Drosophila* eggs applies also to all biological effects, and, in particular, to the radiation effects produced in the tissues of the human body, both normal and pathological. Such a generalization, however, would make skin erythema also independent of the wave-length because: (1) No matter how complex a biological phenomenon skin erythema is, it must be reducible to a number (however large) of "simple" biological reactions; (2) if each "simple" reaction is independent of the wave-length, then the complex reaction made up of these component parts cannot possibly depend on the wave-length. But, of course, we have not considered the influence of the scattered radiation. So far as we know at present, the only relevant difference which scattering introduces in this problem is a change in wave-length. This change in wave-length obviously cannot have any influence on the component simple reactions if they are independent of wave-length, and therefore it cannot have any influence on the erythema reaction. Accordingly, the indisputable difference in behavior between *Drosophila* eggs and human skin, with regard to wave-length, implies either that (1) at least some biological effects (whether simple or complex) depend on the wave-length, or that (2) scattering introduces some hitherto undiscovered factors.* The simple admixture of scattered radiation to the primary beam does not play an appreciable part in the effects produced on *Drosophila* eggs or wheat seedlings. Packard has shown, for instance, that the percentage of roentgen radiation scattered back by a block of paraffin is not very different whether it is measured by a small ionization chamber or by its lethal effect on *Drosophila* eggs.[9] Our first experiments with wheat seedlings and *Drosophila* eggs were made with the materials supported in air, and directly over a tank of water, using both roentgen and gamma rays. The ratios obtained were essentially the same. Hence, if scattering is responsible for the wave-length dependence of skin erythema, it is not simply because it introduces radiation of different wave-lengths.

* Of course both of these alternatives are possible simultaneously.

Let us now examine the question from the radiotherapeutic aspect. What bearing have these experiments performed with *Drosophila* eggs and tiny pieces of tumor tissue irradiated "in air" on the problems of radiation therapy? Here we are always dealing with masses of tissue in which there is always considerable scattering. If scattering is so fatal to the wave-length independence of the biological effects of roentgen rays, as it is in the case of skin erythema, it must also make the effects produced on other human tissues depend on wave-length. Hence the results of experiments made with animal tumors irradiated in small pieces outside the body, purporting to show that the independence of wave-length exists also in the lethal action of roentgen rays on tumor cells, are of no practical significance.

Granting that scattering is responsible for the deviation of the erythema reaction from the "law" of wave-length independence, it follows that the *magnitude* of the deviation must depend in some way on the amount of scattering. In the treatment of deep-seated tumors by roentgen rays, the radiation traverses first some normal tissues before reaching the tumor. Hence the scattering in these normal tissues (including the skin) is always different from that which takes place in the tumor. Furthermore, this difference in scattering depends on the wave-length of the radiation used. Accordingly, it follows that (1) the magnitude of the deviation from the law of wave-length independence is different for normal and tumor tissues as they are necessarily irradiated in practice, and (2) this difference depends on the quality of radiation used (and probably on other factors). Thus it is evident that the existence of a wave-length differential action of radiation in cancer therapy, which is stoutly denied by many, is made possible by the very phenomenon which they invoke to account for the "peculiarities" of skin erythema.

It should be noted that the differential action just discussed is brought about supposedly by differences in scattering which are dependent on the relative positions of normal and cancer tissues (and other factors). It is not, according to this view, an intrinsic property of the tissues themselves. The results of Packard's and Wood's experiments with *Drosophila* eggs and animal tumors show that within certain wave-length limits there is no true differential action in this case. Our results obtained under similar conditions, using wheat seedlings, *Drosophila* eggs, and mouse tails, and extending the range of wave-lengths to gamma rays, do not give evidence of a very marked true differential action. On the other hand, if it can be shown definitely that the "anomalous" behavior of skin erythema is not due to the scattering phenomenon, the existence of a true differential action with regard to wave-length is well established. For, as already brought out in the example given at the beginning of this paper, the radiosensitivity ratio between human skin and *Drosophila* eggs obtained with gamma rays is very different from that obtained with ordinary roentgen rays (6.1 and 1.3 respectively). If a similar dependence on wave-length should obtain for the radiosensitivity ratios between normal and pathological tissues, the quality of the radiation used in radiation therapy would play an important part in the clinical results obtained.

As a matter of fact, there can be little doubt now about the influence of wave-length *per se* in the practical therapeutic application of radiation. We have pointed out in the preceding paragraphs that the marked difference in behavior with regard to wave length, between human skin as ordinarily irradiated and other living tissues, leads to the inevitable conclusion that the relative radiosensitivity of at least some living tissues varies with the quality of the radiation used. The same final conclusion is reached whether we account for our experimental results on the basis of a true differential effect or we attribute the anomalous behavior of human skin to the scattering process. That a similar differential action obtains in the case of normal

and pathological tissues in the human body is further substantiated by clinical observations. According to the experience of radiologists who have used ordinary roentgen rays and radium packs extensively, the differential action of radiation favors the use of gamma rays. Taken in conjunction with our experiments, this means that the (real or apparent) radiosensitivities of normal and tumor tissues irradiated in the human body become more widely separated as the wave-length decreases from that of ordinary roentgen rays to that of gamma rays. Our experiments show that the action of 700 kv. roentgen rays is intermediate between that of 200 kv. roentgen rays and that of gamma rays. Hence better clinical results should be obtained with roentgen rays of higher voltages than are commonly employed at present. In fact, the aim should be to build machines capable of producing "artificial" gamma rays. The clinical impressions obtained at the hospital so far substantiate these results (see Part VI).

The existence of a differential action of radiation with respect to wave-length has been denied in the past, largely on theoretical grounds. It has been argued that if biological effects depend on ionization, what difference does it make whether the ionization is produced by short or long wave-length radiation? We wish to point out in this connection certain phenomena which may very well have a bearing on the problem, and which have not been considered before (so far as we know) in discussions of this subject. It is an essential requisite for all ionization measurements that a voltage high enough to produce saturation must be applied to the ionization chamber. Accordingly in such measurements all (or substantially all) the ions produced in the chamber or between the collecting electrodes are utilized, since recombination is effectively prevented. It has been shown by the experiments of Millikan,[7] of Compton, Bennett, and Stearns,[1] and of Sievert,[10] that when the pressure of the gas in the chamber is raised to 30 atmospheres or higher, recombination of the ions (produced by gamma rays) is facilitated to such an extent as to make it almost impossible to obtain saturation. The same effect is noted at atmospheric pressure when the ionization is produced by alpha rays.* Here the ions are crowded along the path of the rays and recombination is greatly facilitated. It follows from these experimental facts that the probability of ion recombination in a liquid must be much higher than it is in a gas at ordinary pressure. Furthermore, the rate of recombination must depend on the ion concentration along the path of the ionizing particles. Since the ionizing particles produced by roentgen rays of different wave-lengths have different speeds and produce different ion concentrations per centimeter, it follows that the rate of recombination must depend on the wave-length.

The influence which the rate of recombination has on the chemical effects produced by ionizing radiations is not known. In particular, it is not known whether all the ions produced or only those which survive for a certain time (however short) are responsible for the observed chemical changes. Lind, in his excellent monograph on "The Chemical Effects of Alpha Particles," presents experimental evidence to show that the number of molecules taking part in a chemical reaction brought about by ionizing radiations may be several times larger than the number of ions actually produced in the medium. He accounts for this on the "cluster" hypothesis, whereby an ion which is attached to a cluster of molecules favors the change of some or all of these molecules instead of only one. Accordingly it is possible, and even probable, that some of the ions recombine and take no part in the chemical action, while others influence a number of molecules in their immediate vicinity. Since, as we have seen, the rate of recombination depends on the wave-length of the primary ionizing agent, the magnitude of the chemical change *for the same number of ions initially produced*

* This has been known for many years.

must also depend on the wave-length. The number of ions initially produced, therefore, is not necessarily a measure of the resultant chemical change when radiation of different wave-lengths is used. The extension of these considerations to the biological action of radiation is obvious. Thus the existence of a biological differential action with respect to wave-length does not necessarily contradict accepted physical and chemical concepts.

It is probable that the results of the chemical experiments reported at this symposium, and others which have been planned, will throw considerable light on the subject just discussed. Time has not permitted a careful analysis of the data from this point of view. It is evident, however, that the reactions depend on something more than the actual ionization produced in the solutions.

In conclusion, I wish to say that the cooperative work presented at this symposium has been very stimulating to all of us. New lines of attack have suggested themselves and a large program for further study has been formulated. The wholehearted cooperation of my collaborators has made possible whatever success we have had so far, and I am glad to express my indebtedness to them.

I also take pleasure in thanking Dr. Coolidge and the officers of the General Electric Company for the opportunity of working with 700 kv. roentgen rays, which was made possible to us through their generosity and kind consideration.

SUMMARY

The results of the experimental work carried out with 165 to 200 kv. roentgen rays, 700 kv. roentgen rays, and gamma rays, presented at this symposium, are discussed chiefly from the point of view of their applicability to radiation therapy.

It is shown that the experiments with wheat seedlings, *Drosophila* eggs, and mouse tails, taken by themselves, do not establish the existence of a differential action of radiation with respect to wave-length. However, the generalization that there is no such differential action is not warranted.

The difference in the behavior of these biological materials and a small spherical ionization chamber with thin celluloid walls is small and probably not significant considering the probable error of such biological determinations. Accordingly it may be said that a fairly direct relation exists between ionization in this chamber and the biological effects studied in the three materials employed over a range of wave lengths covered by 200 kv. roentgen rays and gamma rays.

The experiments on skin erythema show definitely that there is a very marked difference (300 to 400 per cent) between this reaction and either the ionization chamber readings or the biological reactions studied when the quality of radiation is varied from that of 200 kv. roentgen rays to that of gamma rays.

This result, which cannot possibly be attributed to experimental errors, may be accounted for on two bases: (1) Either it is due to a true differential action of radiation for human skin as compared to the other biological test objects, or (2) it is due to the scattering of radiation by body tissues.

If the first conclusion is correct, then it is reasonable to expect a true differential action to exist also in the case of normal and pathological tissues in the human body.

If the second conclusion is correct, it follows logically that an apparent differential action must exist in the case of normal and pathological tissues in the human body as ordinarily irradiated with external sources.

In either case the practical result is that quality of radiation *per se* very probably plays an important part in radiation therapy.

The clinical impressions of those who have had much experience with the use of roentgen rays and gamma rays makes this probability almost a certainty.

The experiments with 700 kv. roentgen rays show that the behavior of this quality of radiation is intermediate between that

of 200 kv. roentgen rays and gamma rays. Hence better clinical results may be expected from the use of very high voltage roentgen rays on two grounds: (1) Because of greater depth doses obtainable, and (2) because of the very probable greater differential action on the tissues of the human body, whether direct or indirect.

Certain physical and chemical phenomena bearing on the theoretical considerations of a differential action of radiation with respect to wave-length are discussed. It is shown that the existence of such differential action is not in contradiction to accepted physical and chemical concepts.

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DISCUSSION OF SYMPOSIUM ON THE RELATIVE EFFECTS PRODUCED BY 200 KV. ROENTGEN RAYS, 700 KV. ROENTGEN RAYS, AND GAMMA RAYS

Dr. C. C. Little, Bar Harbor, Maine. (Discussion of biological problems.) I am sure that we all appreciate what it means to undertake to report on such a comprehensive cooperative piece of work as the Memorial Hospital group has just given us the pleasure of hearing. All that I have to say from the point of view of one biologist is not aimed at the work which they have reported on, but is simply to try to point out some of the factors which enter into this extremely complex matter of using biological material with which to test these physical units.

There is no question that biological material reacts in different ways to different wave-lengths. I think that has been shown very clearly. The question then is whether we can refine biological material to a point where the nature of that difference can be more clearly defined than it is at present. It seems to me that first of all in any of this work it is extremely important to be perfectly sure that you are working with what might be called a pure line of biological material. I am sure that the workers of the Memorial Hospital group have done that. As I say, this is not directed toward them but is talking about the situation in general.

If one took 50 mouse tails at random, for example, it would be surprising to know the tremendous potentiality for variations which those 50 mouse tails would have. In the first place, they would vary according to race. Certain races of mice have longer tails which grow faster and more vigorously than others. They would vary in number of vertebrae; they would vary in proportionate length of the different vertebrae in the tail, and some of them in certain races would even have areas of spontaneous necrosis leading to spontaneous amputation. It is clear, therefore, that unless careful control is kept of the mouse tails with which you work the fact that they all look like perfectly good mouse tails may turn out to be a snare and a delusion. The same principle applies to most, if not all, morphological and physiological characters in mammals.

There is the question of the use of averages to denote differences. Those are properly used, and have been used in the papers which you have listened to today. There is a phase of

them, however, that is of very great interest. That is the degree of variability around the average which is presented to us as the criterion of difference. For example, in the spontaneous incidence of mammary cancer in mice, it is possible to have two strains of mice unrelated to one another in which the average age of spontaneous cancer incidence is at eleven months (of the age of the mouse). These two strains may however show very different variation curves, so that one of them groups from the seventh to the twelfth month as the extremes of age at which cancer can appear, while another, with exactly the same average age of cancer, may show its earliest cancer at three and one-half months and run up to nineteen months. If you are using averages it will be of great interest to see the full results of such work as we have here today and of other experiments, which I am sure will follow, expressed in terms of the variability from the mean (the average which is given), as the index of difference.

We would probably be able to detect biological characters which were much more suitable for us than others because of compactness, closeness of variability, and the smallness of their standard deviations from the mean.

I think it would be extremely interesting to study the effects of these agents on seedlings of a single, pure line of wheat, for example, while those seedlings were being made to do some work. For instance, turning the seedling so that it had to compensate in growth, to see to what extent that would modify the results that you get with a seedling in a given and fixed position. You might get an interesting line on the nature of the difference of the effect by making the organism which you are testing do some physiological work and then comparing it with the control which was more or less idle.

I am also wondering whether it wouldn't be interesting—I suppose it has been done and I shall probably simply show my own lack of comprehension of it by suggesting it—to work on a cyclic phenomenon, such as the estrual cycle, to measure some of these effects. One of the troubles with biological material is that natural selection has made it extremely compact. It has condensed the greatest amount of efficiency into the smallest working unit that it can to fulfill the required needs. Sometimes, however, natural selection has preserved a process which has an effect on the biological unit that you are studying such as a stereopticon does in enlarging objects which we wish to see. The estrual cycle, or some such phenomenon, pulls out the physiology of a process to a convenient length. The age of cancer incidence is a very comfortable thing to watch because it is a process pulled out over a sufficient length of time so that variations expressed in percentages of the phenomenon are actually larger. As a result our stupid statistical eyes can see them more clearly than they can differences in compact, fast-working processes.

It seems to me that work of this type which the Memorial Hospital group has reported today is an extremely encouraging thing, and that that very difficult no man's land between biological experimentation and clinical application of these principles, which are so important, is in a very fair way to being bridged by efforts of this group. I think they are very greatly to be congratulated, and I am sure you all feel the same way.

Dr. Otto Glasser, Cleveland, Ohio. (Discussion of physical problems.) When I was asked to discuss these papers, I accepted the invitation with great pleasure, the more so since, strange as it may seem, we physicists now agree on most of the problems under discussion. While looking at the interesting scientific exhibits this morning, I was asked by a number of my friends what I thought about the new super high voltage roentgen rays. Some radiologists seem to feel that they give great promise as a new therapeutic agent, and others deny that they have any practical value. I am frank to say that I do not know, since I have not had the opportunity to work with roentgen rays produced by more than 200,000 volts. I have done some work in measuring the quantity and quality of roentgen rays produced with 200 kv., and also of gamma rays of radium, but it would be difficult to interpolate in order to obtain data for roentgen rays produced with higher voltages. I feel that those who have installed and are working with the new high voltage apparatus are pioneers and we must wait for their reports to answer our questions. Today we have heard one such report which is excellent.

I should like to say a few words in regard to the physical methods of measuring radiation intensity by means of small ionization chambers. Mrs. Quimby has shown that there is a difference between the relative intensities meas-

ured by ionization chambers constructed of different materials. It seems to me that small metal chambers are not suitable for making these measurements. We should use exclusively small chambers of the air-wall type and of a given wall thickness. Mrs. Quimby has shown in the table that they are very satisfactory for measuring radiation intensities and that the ionization current produced runs parallel with that produced in a large open air ionization chamber over an extended range of wave-lengths.

In this connection, I wonder whether we are not now entitled to go a step further. It is necessary to extend intensity measurements beyond the range of rays produced at 200 kv., up to 700 or even 1000 kv., and thence to gamma rays of radium. Several years ago it was shown that probably this will be possible only by using the small air-wall ionization chamber with some kind of measuring instrument similar to the condenser dosimeter.

The observations of Mrs. Quimby, and of other workers, have confirmed these results and hence I should like to suggest measuring radiation intensities over this whole range in a unit which we may call the r (gamma) unit, by using the small chamber with a wall thickness of 1 millimeter. I feel that this r-unit is the same as that defined internationally but since it is not yet possible for extremely hard rays, to measure with an open air ionization chamber, it is not justifiable that it be designated as the roentgen (r) unit, but it had better be called the r (gamma) unit. If at a later date, it develops that corrections are necessary, these can be made easily if the method of measurement is always stated definitely.

The values for scattering and back-scattering, as presented in the tables, again show how difficult it is to measure satisfactorily the various types of radiation. No doubt, according to the Compton effect, the wave-length of scattered rays is increased and hence it is difficult to measure the total intensity, for instance in the depth, unless there is absolute certainty that the ionization chamber is entirely independent of the wave-length. Still it is possible that the wall of the chamber absorbs the softest scattered rays and that, for this reason, these are not registered. It would be interesting to measure radiation intensities by biological or chemical methods, not only at the surface, as shown in several of these papers, but also in the depth of a water phantom. This would permit the softest rays to be registered and I am quite sure that the results obtained, for instance for the percentage deep dose, would not quite agree with the present data which have been obtained by means of ionization chambers.

Regarding the iodine reaction which was used as a method of measuring radiation intensity, I should like to ask whether there is not some peculiar effect inherent in this reaction. I remember that some years ago Glocker used the same reaction for roentgen-ray measurements and found that the chemical reaction continued even after the influence of the roentgen rays was removed.

I have worked with *Drosophila* eggs for some time, experimenting with roentgen rays produced at 200 kv. and with gamma rays of radium. I have not found exactly the same difference for various wave-lengths that Dr. Henshaw has reported, but as a whole, our results agree quite well. Dr. Failla has stated that if he compares skin reactions with doses determined with a small ionization chamber, he finds that a much higher dose, as measured in roentgens, is necessary for radium rays than for roentgen rays in order to produce the same effect upon the human skin. This agrees very well with my experience, and also with that of Mayneord of London. From this effect on the skin, however, it would be extremely difficult to draw any conclusions in regard to the reaction of other types of tissues to various wave-lengths. This is one of the important points brought out by Dr. Failla and his coworkers.

DR. HENRY SCHMITZ, Chicago. (Discussion of clinical problems.) With rays produced by 500 kv. or more, direct absorption is reduced to a minimum and indirect absorption by scattering becomes all important. The distribution of intensities in the depth differs depending on direct or indirect absorption. Hence the biological effect may differ.

Scattered rays are formed when rays impinge upon matter. If the matter is crystalline then the primary ray remains unmodified. If the matter is non-crystalline then the primary ray is modified. The primary ray loses kinetic energy by the recoil and the emerging ray has a longer wave-length. This is the Compton effect. If the body traversed by the rays has an appreciable volume as a water phantom or the human body, then the Compton effect is not a single phenomenon but recurs repeatedly wher-

ever striking matter. Each time energy is given off which is transformed into an electron when becoming absorbed, and each time the wave-length becomes correspondingly longer until the primary ray is completely absorbed.

Rajewsky has determined the degree of absorption due to the Compton effect and found it equal to one Compton scatter in bodies not more than 2 cm. deep but equal to three or four times the single Compton scatter if 10 or more centimeters deep. It appears therefore desirable to use extremely hard radiations in deep therapy as with a decrease in wave-length an increase in scattering occurs and scattered rays are absorbed in the depth of tissues.

Rajewsky also determined the region where scattering reached maximum. The depth of the maximum absorption curve (M.A.C.) depends on the wave-length, the size of field of entrance, the focus skin distance and the filter.

If the wave-length corresponds to roentgen rays produced at the following voltages with a focus skin distance of 50 to 60 cm. and with a size of field 20 cm.^{2} then at

100 kv. the M.A.C. is 2.5 cm. deep
200 kv. the M.A.C. is 5.5 cm. deep
700 kv. the M.A.C. is 8.5 cm. deep
1000 kv. the M.A.C. is 14.0 cm. deep
2000 kv. the M.A.C. is about 19.0 cm. deep

For filtered and unfiltered radiations with 200 kv. and no filter or 1.0 mm. copper plus 1.0 mm. aluminum filter maximum absorption occurred at 3 and 6 cm. respectively and the intensities were 8 and 20 per cent of the surface dose.

If the entrance fields were 10 and 20 cm.^{2} and the other factors remained constant then maximum absorption occurred at 4 and 6 cm. respectively and the intensities were 17 and 22 per cent of the surface dose.

If the focus skin distance was 40 and 60 cm. and the other factors remained constant then the maximum absorption occurred at about 6 cm. but the intensities were 22 and 30 per cent of the surface intensity.

The maximum absorption curve may be plotted against the intensities and the resulting graph is a straight line.

Glasser, and others, have found that the number of roentgens to produce a skin erythema dose varies with the quality of radiation used. More roentgens are necessary as wave-lengths decrease beyond λ eff. 0.217 i.e., 130 kv. For gamma rays it is about 2000 r and for 200 kv. 900 r with back-scattering. These observations run parallel to the direct relations existing between the maximum absorption curve and effective wave-lengths and if r-values are plotted against wave-length and maximum absorption layer probably a straight line is obtained enabling one to read off the r-values for skin erythema doses for varying wave-lengths.

Perusal of the doses given by Dr. McNattin may be expressed in values of r if such a linear graph is used and the following results are obtained:

Radiation	Skin Doses		Tissue Doses at 4 cm. Depth	
	T.E.D.	r	T.E.D.	r
200 kv.	8.0	4800	6.0	3600
700 kv.	5.3	4240	4.7	3760
Gamma rays with 10 cm. F.S.D.	2.8	5600	1.7	3400

The reactions with 200 kv. were almost prohibitive as tissue tolerance was over-reached; with 700 kv. they were less severe and more bearable, and with gamma rays least severe and rapidly healing with the least latent effect. Resorption of growth was complete with 700 kv. and gamma rays.

The symposium given by the Memorial Hospital presents a turning point in cancer radiation therapy. It is a big step in advance and will bring us nearer to the control of cancer. In the future the depth of the tumor mass will be determined. The radiation will then be chosen having the maximum absorption layer at this depth and hence maximum absorption of the Compton scatter.

Dr. Douglas Quick, New York City. (Discussion of clinical problems.) I must apologize for my inability to be present personally at this symposium, and I am taking the liberty of asking our chairman to read the few remarks which I have prepared.

My discussion is limited to the clinical phase of the presentation. The laboratory papers, however, would of necessity have some bearing on this so that I trust I may be pardoned if certain points, which I may mention, are covered by these papers.

I have not had the opportunity of going over the paper which is to be read by Dr. Duffy. I

have reviewed Dr. McNattin's paper, and my discussion will, therefore, be limited to it.

While the symposium deals in a comparative way with the relative effects of three ranges of wave-length, the high point of practical interest centers around the 700 kv. radiation. Dr. McNattin has presented a very frank report of what has been done with these various qualities of radiation at the institution with which he is associated. Admittedly, however, the paper does not present a complete clinical picture of the comparison of three different qualities of radiation. It is only a preliminary report. A great deal more of clinical work—work of a different character than that already done—will be necessary before a conclusive comparison may reasonably be made. The information derived from such work is sorely needed. I believe, however, that those of us who have had experience with 200 kv. roentgen rays and with the radium pack will agree with the impressions which Dr. McNattin has expressed.

His physical calculations on the three qualities of radiation, with gamma rays charted for varying distances and expressed in ratios of relative clinical efficiency are very clearly set forth. They are not only most interesting, but highly instructive. They are in keeping with the rather empirical observations made on 200 kv. roentgen radiation and gamma rays over a period of years. They fit very closely with the biological experiments of Failla and Henshaw. There is no reason to suppose that 700 kv. roentgen radiation is, from a clinical standpoint, anything but intermediate. The practical point with most of us is just where in the scale does it fit between the 200 kv. roentgen radiation and the gamma rays from the radium element pack. Since the clinical experience to date has fallen in line with the experimental work of Failla and Henshaw, it would seem only reasonable to place 700 kv. roentgen radiation in clinical value where it has been placed by biological experiment. Even though no conclusive data are as yet available, this quality of radiation seems sufficiently assured to be clinically advantageous if it can be made practical, technically and economically.

The radium element pack is indispensable as a comparative guide and standard in a completely equipped radium institute. For routine clinical work, however, it is economically impractical. It is a stimulus toward the production of that which we hope is being afforded us in the 700 kv. equipment. While this equipment is being studied further experimentally, and improved from an engineering standpoint, we must not lose sight of the vast amount of improvement which may be made through the better application of our present day 200 kv. roentgen radiation. I refer to the clinical improvement which may reasonably be expected through a better understanding of such factors as increases in filter, focal distance, and time of exposure, as well as in the various possible methods of fractionating the individual doses. A vast amount of work in this direction remains as yet largely untouched.

It occurs to me that the comparative picture might be somewhat simplified and rendered strictly more accurate if the 200 kv., 700 kv., and gamma radiation were referred to in terms of average or effective wave-lengths. The 200 kv. roentgen radiation referred to in this paper is that filtered by 0.5 mm. of copper plus a secondary aluminum filter. If this filter were increased, as many of us believe to be advantageous, it would appreciably change the effective wave-length, and yet it is still 200 kv. roentgen radiation.

I regret that Dr. McNattin has not interposed in his paper something of the relative effects observed histologically on different types of tissue irradiated by the different qualities of radiation which he has employed. I hope that something has been presented in the experimental papers to indicate the relative change in the quality of the three types of radiation under discussion on passing through tissue. Judging from the work presented by Mrs. Quimby and Dr. McNattin in the August, 1932, *American Journal of Roentgenology and Radium Therapy*, it would seem reasonable to expect that there would be less change in the quality with 700 kv. roentgen rays than with 200 kv. roentgen rays. This, it would seem, would represent a clinical advantage in favor of the higher voltage radiation.

Dr. McNattin has given us an excellent clinical picture of the primary reactions, both local and general, to the various qualities of radiation, and at varying intervals after treatment. His reference to the difference in late skin changes between 200 kv. roentgen radiation and gamma radiation is especially worthy of emphasis.

His statement concerning the mild local and constitutional reactions to 700 kv. radiation is

apt to be confusing. The quantities employed with this quality of radiation are not quite comparable to those used in either the lower voltage radiation or with the gamma-ray doses referred to.

The data which he has presented on the use of the 4-gram pack at 6, 10, and 15 cm. is extremely interesting. Indirectly it lends substantial support toward increasing the time of exposure and raises the question as to whether the skin erythemas and relative absorption percentages as governing factors represent the final answer to actual clinical efficiency. There is a point beyond which the clinical results obtained through the use of greater distances, increased filter, and prolongation of time, are not in keeping with that which would be regarded as the dosage of maximum efficiency from a strictly physical standpoint.

Dr. McNattin has made suggestions as to how a comprehensive clinical experiment might be carried out in a comparative way. Such a piece of work is much needed as a guide to the smaller clinics, as well as to individuals engaged in cancer practice. We may hope, therefore, that in the near future we shall be favored with the results of a more extensive clinical research, comparable in its detail and accuracy with that which we are already receiving from the biological and physical laboratories.

Dr. E. T. Leddy, Rochester, Minn. I have been greatly interested in the discussion by members of the staff of the Memorial Hospital of the ultra high voltage treatment of carcinoma and have been impressed by their reports. I am frank to admit that I do not know what it is all about; therefore what I say should not be interpreted as either for or against the use of this type of radiation.

My daily experience is with patients suffering from cancer in whom cure is out of the question. For this reason, I prefer to speak of palliation and not of cure. I think it is proper to talk about epilating the skin, about producing radiodermatitis of varying degree, about upsets from treatment of varying degrees of severity, but I think that in many cases the surgical or radiological procedures can be justified only by such improvement in prognosis as the patient may derive.

I do not feel that we have exhausted the possibilities of roentgen-ray treatment as now used. Moreover, in view of the fact that the use of rays of extremely short wave-length is still largely experimental, we must not allow ourselves to be stampeded in our natural desire for progress and go into ultra high voltage treatment until the leaders of research in this field, such as the Memorial Hospital, have furnished indisputable evidence that such a step is not only justifiable but definitely indicated.

Dr. Failla (closing). Perhaps I might add a word to what Dr. Glasser said about the desirability of expressing quantities of radiation throughout this range in some unit that we all can use. I think that is very desirable but it depends upon the unanimous agreement that we shall measure radiation of these different qualities in a certain way. It is always difficult to get a unanimous agreement on anything, and for that reason, at the present time it is really impossible to adopt any one measuring chamber for this purpose. Furthermore, we are planning experiments which I hope will decide the question as to whether with the small chamber we are measuring roentgens or are measuring something else when we go to 700,000 volt roentgen rays and gamma rays. Naturally, in the meantime I am rather reluctant to adopt any particular scheme.

The important point, as I have mentioned a great many times before this Society and other societies, is that we must not expect the same number of roentgens to produce the same biological effect, when the quality of the radiation is very different. This is, perhaps, another reason for not attempting at the present moment to express gamma-ray and 700 kv. doses in terms of the roentgen. The impression might be created that the same number of roentgens of gamma rays or 700 kv. roentgen rays will produce the same biological effect. That certainly is not true in the case of human skin, as Dr. Glasser pointed out some years ago, and as we have shown today. Whether it is true in the case of tumors is something we do not yet know. It seems to me that the best thing to do is to emphasize this difference, and to bear in mind that for the present it is best not to express gamma-ray quantities in terms of the same unit that we use for roentgen rays produced at 200,000 volts.

ROENTGEN DIAGNOSIS AND LOCALIZATION OF OPAQUE FOREIGN BODIES IN THE AIR PASSAGES*

By WILLIS F. MANGES, M.D.
PHILADELPHIA, PENNSYLVANIA

A CLINICAL diagnosis of foreign body in the air passages depends upon the history of the accident and the presence of physical signs of irritation, obstruction, or of exudate in various portions of the air passages. In adults, the history is usually clear and the nature of the foreign body is definitely known, so that even a duplicate can be furnished. In children, this is often not the case. The child has a choking and strangling attack while playing on the floor or elsewhere and may or may not be within sight of an older person, but the history of sudden attack should be sufficient to lead one to suspect the aspiration of a foreign body. The initial strangling attack is usually followed by recurrent attacks of coughing but there soon develops a period of calm, described by Jackson, which leads parents, as well as physicians, to believe that the foreign body has been expelled or to forget the importance of considering the original attack due to foreign body. The coughing attacks recur, however, and they are associated with more or less febrile reaction so that there develops a clinical diagnosis of anything from bronchitis to pneumonia or lung abscess. It is remarkable that such patients, especially children, are permitted to go for months and even years without a roentgen examination. In many of our cases it is the parents who insist upon this examination rather than the physician in charge. For example, a child about six years of age had a coin in the trachea for three years. He was treated constantly for chronic bronchitis, bronchopneumonia, asthma, and other pulmonary lesions. The foreign body was discovered only after the parents insisted upon a roentgen examination.

The list of this type of unsuspected foreign bodies of long sojourn is quite a long one. In the absence of a history of the accident, foreign bodies should be suspected when there are recurrent attacks of illness associated with the respiratory tract. Jackson insists that every child with a cough should be roentgenographed. As a rule, the clinician who has given the matter serious study can differentiate between the physical signs and symptoms of foreign body and those of other lung diseases, but, taken as a whole, the medical profession is not educated to the point of being able, by means of physical signs and symptoms, to make a diagnosis of foreign body in the air passages in the absence of positive history. There is a tendency for most physicians to believe that foreign bodies are "swallowed" and not "aspirated." As a matter of fact, the accident of swallowing a foreign body is more frequent than that of aspirating it, and it is true that a definite percentage of the foreign bodies swallowed pass on through the alimentary tract; but all of the foreign bodies that enter the respiratory tract remain there, with the exception of possibly 2 or 3 per cent that are expelled spontaneously by the coughing effort. A diagnosis, then, from a clinical point of view is in many instances unsatisfactory and unreliable.

ROENTGEN DIAGNOSIS

The first and most important consideration is the quality of the roentgenogram that should be depended upon to demonstrate the presence of a foreign body or eliminate its possibility. The roentgenograms should show clearly the outline of the larynx, the trachea and its bifurcation, both in the anteroposterior and lateral views. This demands that exposures be

* Read at the Thirty-first Annual Meeting, American Roentgen Ray Society, West Baden, Ind., Sept. 23–26, 1930.

made in a small fraction of a second, especially in young children, when one cannot gain the cooperation of the patient. If there is sufficient penetration to demonstrate these parts, there will also be sufficient penetration to reveal the presence of a metallic foreign body back of the heart, below the level of the dome of the diaphragm, or in a moderately dense pathologic process; but less penetration may readily be responsible for overlooking a foreign body in such areas. It is often necessary to repeat the exposures many times before getting entirely satisfactory results.

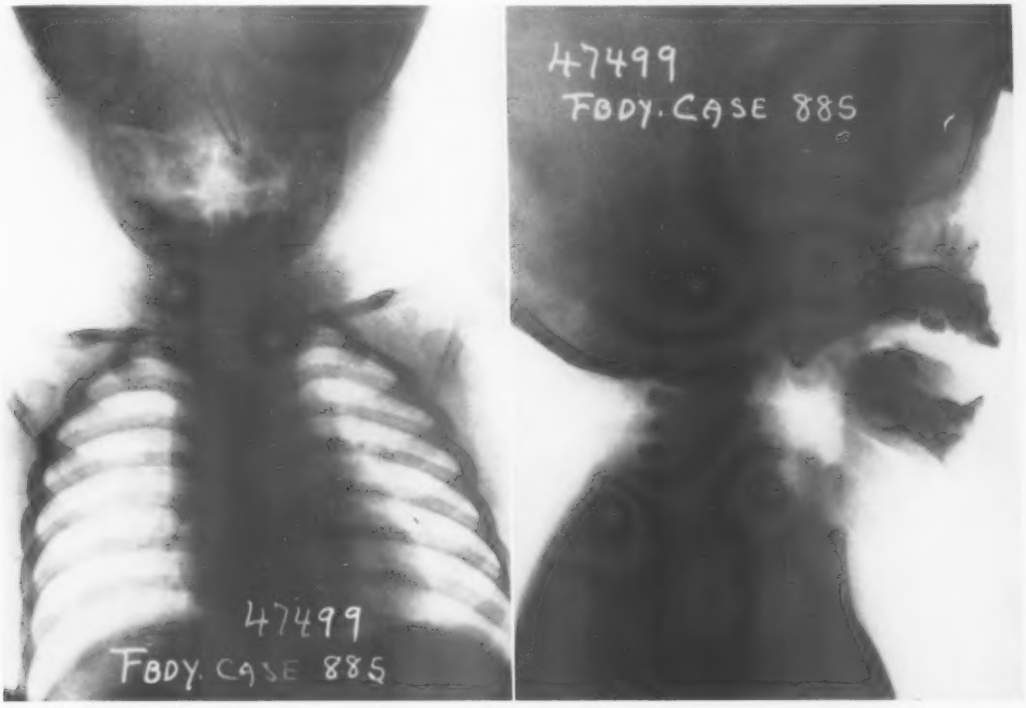

Fig. 1. Safety pin in the nasopharynx, entirely above the soft palate. Note defective keeper.

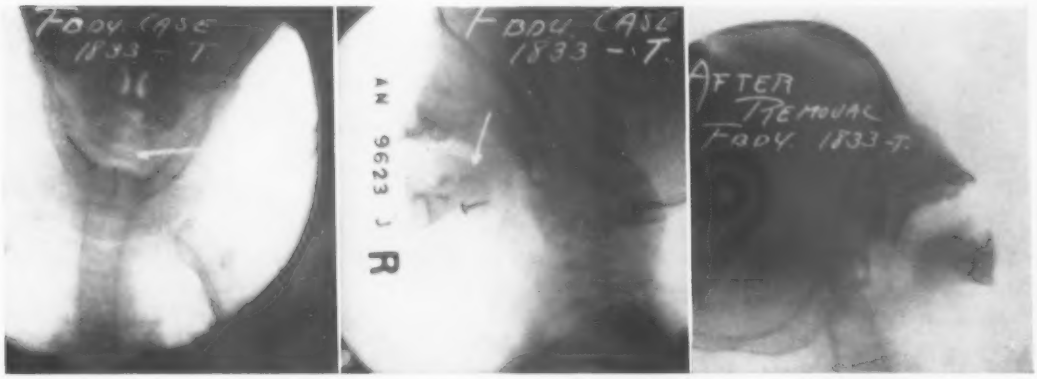

Fig. 2. The tack is in the floor of the mouth on the left side. It was supposed to have been swallowed.

The next most important consideration is the area to be included in the examination (Figs. 1 and 2). One should include all of the air passages from the nasal chambers to the depth of the lungs and even the entire alimentary tract because it may be

that a foreign body has been swallowed instead of aspirated and it may be in the abdomen instead of in the chest. A study for foreign body is not complete unless all of these areas have been included. One should also keep in mind the possibility of more than one foreign body being present (Fig. 3).

When the foreign body is of sufficient size and density to cast a dense shadow, comparatively little search is required, but when the foreign body is of less density it seen patients who had had a previous negative roentgen diagnosis from films in which I could recognize positive shadows of foreign bodies. One is particularly prone to overlook the shadow of a root of tooth or of a fragment of bone or of some material that has comparatively little density above that of the surrounding tissue, unless he has it constantly in mind as a probable cause of the disease present.

Some years ago it was my pleasure to present the subject of non-opaque foreign

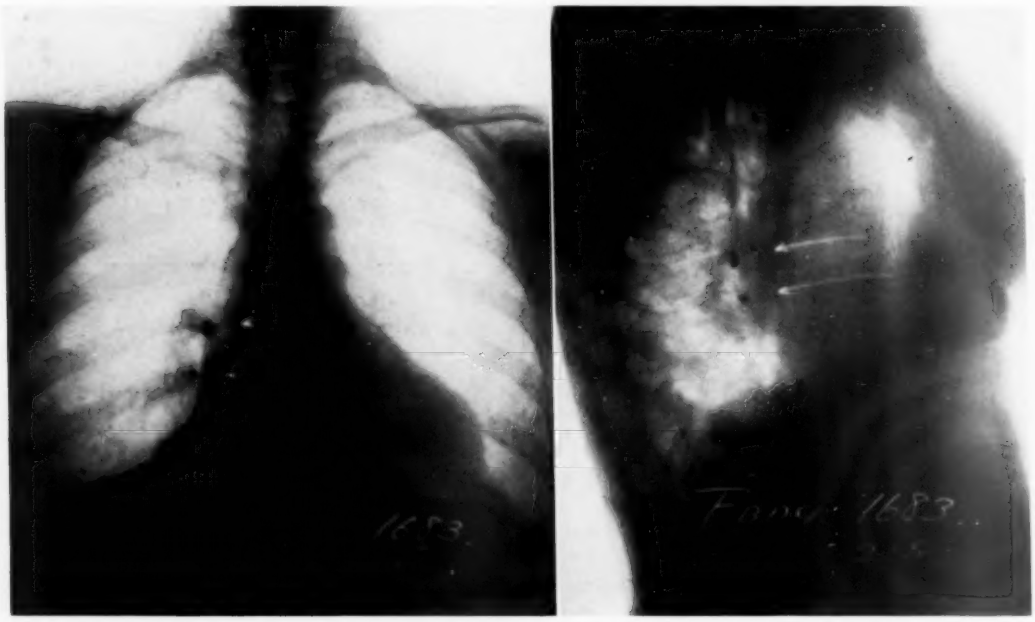

Fig. 3. This shows two fragments of dental filling material.

may be necessary to make extremely careful search of the shadows within the chest before the foreign body can be definitely recognized. I know of a case in which a portion of a crown of a tooth that gave a very positive shadow in a film was overlooked because it was thought to be only one of a number of partly calcified root glands. The foreign body shadow was positive but the detail of shape was overlooked. Then I have seen cases in which the diagnosis of foreign body was made from shadows of calcareous deposits in the lung tissue or lymph nodes with non-opaque foreign bodies elsewhere. I have repeatedly bodies in the air passages and to demonstrate that their presence was determined by the alteration in function or the degree of bronchial obstruction they produce—obstruction either to air or to exudate or both (Fig. 4). Opaque foreign bodies under certain conditions produce these same changes and it frequently happens that we find a foreign body shadow after noting changes in aeration or drainage involving a localized portion of lung.

We have had a number of foreign bodies, portions of which were metallic while other parts were non-opaque (Fig. 5). This is true of shoe buttons and certain other but-

tons and certain toys. The metallic part may be very small and so one must search carefully.

By far the greater majority of foreign bodies, of the opaque variety particularly, are found in the lower lobe bronchi, if they pass through the trachea. They go as far toward the dependent portion of the lung as the lumen of the bronchus will permit, and, after long sojourn, may go even farther by way of the processes of ulceration and destruction of tissue, so that the lower lobe areas must be searched with special care (Fig. 6). I have called attention to this region in a former paper. A localized infectious process, especially in the inner posterior portion of either lower lobe, should be looked upon as of foreign body origin until proof is obtained that there is not a foreign body present. We have a number of cases in which foreign body was not suspected, some of them of the opaque and some of the non-opaque variety, and in the latter instances there was this evidence of a localized pathologic process in the dependent portion of a lower lobe, from which

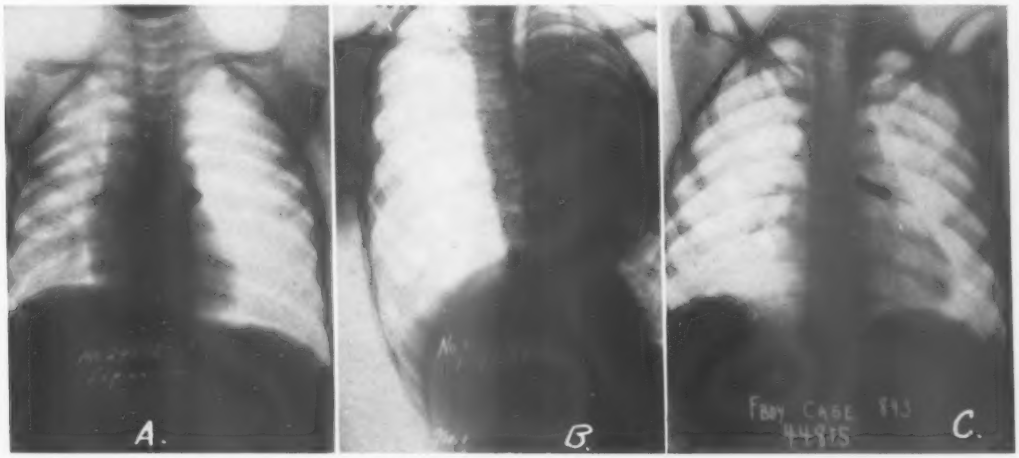

Fig. 4. *A*. A .22 caliber empty cartridge produces obstruction to expiration. Note overdistention of left lung. *B*. A .38 caliber bullet produces complete obstruction of the left main bronchus. Note complete collapse of the left lung. *C*. The foreign body is large enough to produce obstruction but it does not for the reason that it is a piece of lead pipe which permits free passage of air.

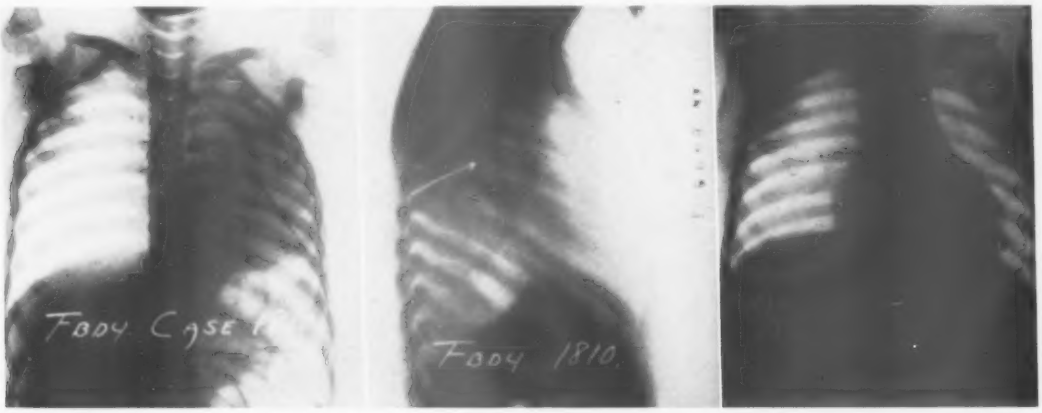

Fig. 5. A shoe button produces complete obstruction of the left bronchus. The metal portion is very small; the rest of the button is non-opaque.

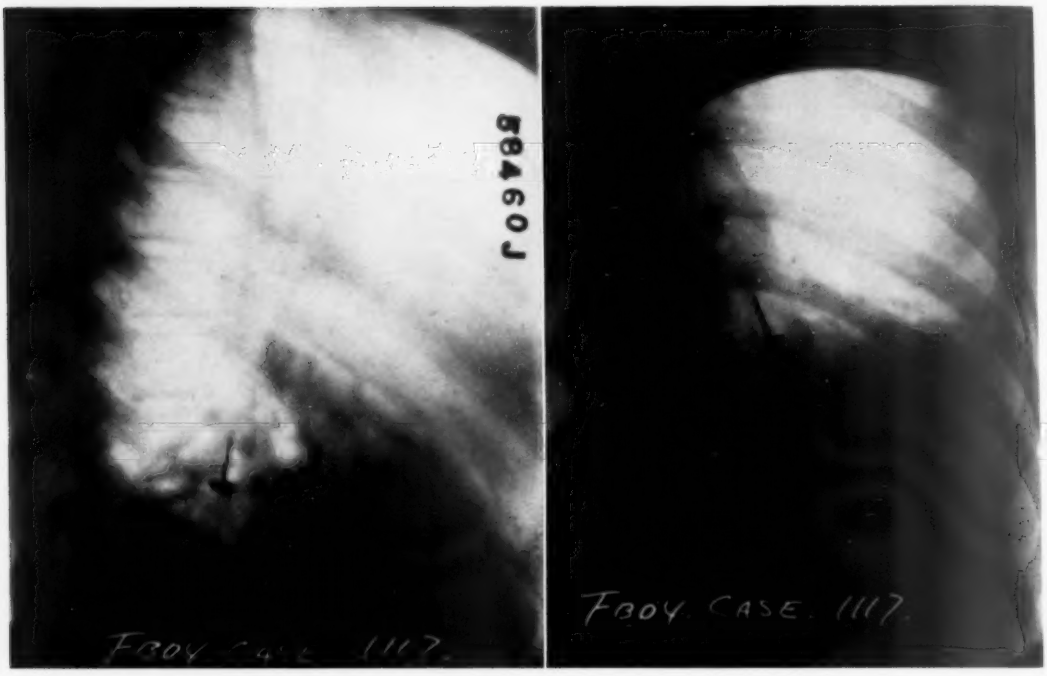

Fig. 6. Umbrella-headed tack in the depth of a bronchiectatic process—a foreign body of long sojourn.

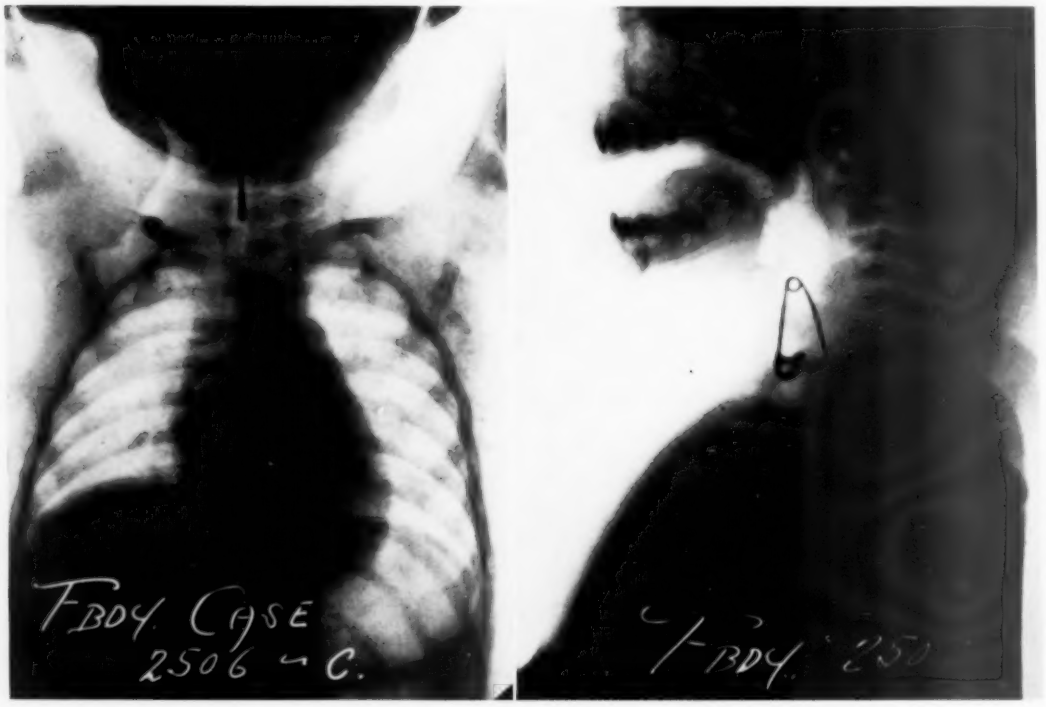

Fig. 7. Note that the point branch of the safety pin has penetrated the posterior wall of the larynx; the keeper has passed through the larynx and is in the subglottic area. It is directly in the median line.

a foreign body—perhaps only a small piece of grass or a small fragment of bone—was found by means of the bronchoscope. In one case a foreign body as large as a shawl pin was present, and the patient, an adult, had had no idea that she had aspirated a foreign body. In another instance a child was supposed to have eaten a bite of apple and choked on it. It was thought that the apple would dissolve. Several months later, after the child had been treated for bronchopneumonia and asthma, I made a diagnosis of non-opaque foreign body in a lower lobe bronchus, and a portion of apple stem was removed. This illustrates another important point, and that is that a roentgenologist even with excellent roentgenograms may overlook a diagnosis of foreign body unless he has it constantly in mind as one of the causes of localized pulmonary infection, and as the most probable cause of such conditions in the dependent portions of the lower lobes, when it is unilateral.

A roentgen diagnosis includes a careful description of the foreign body as to size, shape, condition, number, and distribution, and these points also are essential parts of the next step in the study—localization. The description of the opaque foreign body is of importance to the bronchoscopist because on this description, as well as on the localization, he lays his plans for bronchoscopic removal (Fig. 7). The size of the foreign body may determine the size of the bronchoscope to be used. The size and shape of the foreign body, as well as the distribution of its parts, determine the type of forceps that is necessary for successful removal, so that these descriptions should be made carefully. If possible, one should obtain a duplicate of the foreign body that is present.

Certain types of opaque foreign bodies require special consideration. For instance, staples have always been found with the closed end downward but some of them have been more or less bent out of their normal shape and they vary as to the manner in which they present—that is, the flat side may be forward or it may lie edgewise anteroposteriorly or it may be in an oblique direction. One should by all means obtain a duplicate of the staple or the roentgenogram should be made at a distance of at least 36 inches so that one can, by measuring the shadow, get a definite idea as to the size of the foreign body. The patient must be roentgenographed in such a position as to show the maximum space between the points so that this can be measured accurately (Fig. 8).

Tacks and nails are nearly always found with the heads projecting downward, but occasionally the tack head is uppermost. There is the greatest variation in the size and shape of the head and in the length of the shaft and the condition of the point (Fig. 9). Screws, on the other hand, are usually found with the points downward, so that the size of the head of the screw becomes a matter of real importance because it is the part that presents for forceps contact (Fig. 10). Common pins have a tendency to go to the most dependent portions of the lungs and they may finally go into any one of a large number of small bronchial branches, so that they may be projecting forward or backward; they may be to the inner side of the lobe or out near the axillary border of the lung, and they frequently are found well below the level of the dome of the diaphragm. It is important in these instances to determine, if possible, the distance of the point of the pin from the lumen of the stem bronchus, and at approximately what angle it is that the pin lies to the stem bronchus (Fig. 11). The common pin is always found with the head downward.

The safety pin (Fig. 13) is the most variable of all foreign bodies. I believe that the safety pin is largely an American product—that is, that the safety pin is used far less frequently in other countries than it is in America. We find them in the air passages of children and adults, and they vary in size from the smallest to pins that are 2 or 3 inches in length. We find them open or closed, and in every conceivable position and portion of the respiratory tract from

the nasopharynx to the lower lobe areas. They constitute about 12 per cent of all foreign bodies, including those of the alimentary tract as well as those of the air passages. The majority of them are open, usually with the open end uppermost when in the air passages; but even in this location one of the largest safety pins in Jackson's collection was found with its open end downward, the keeper branch being in the right lower lobe bronchus and the pointed branch in the upper lobe bronchus. They occur frequently with the open end downward in the esophagus, presenting this way because they have been regurgitated from the stomach. Also the pin may be swallowed or aspirated when closed and then open in the esophagus or bronchus. It is ex-

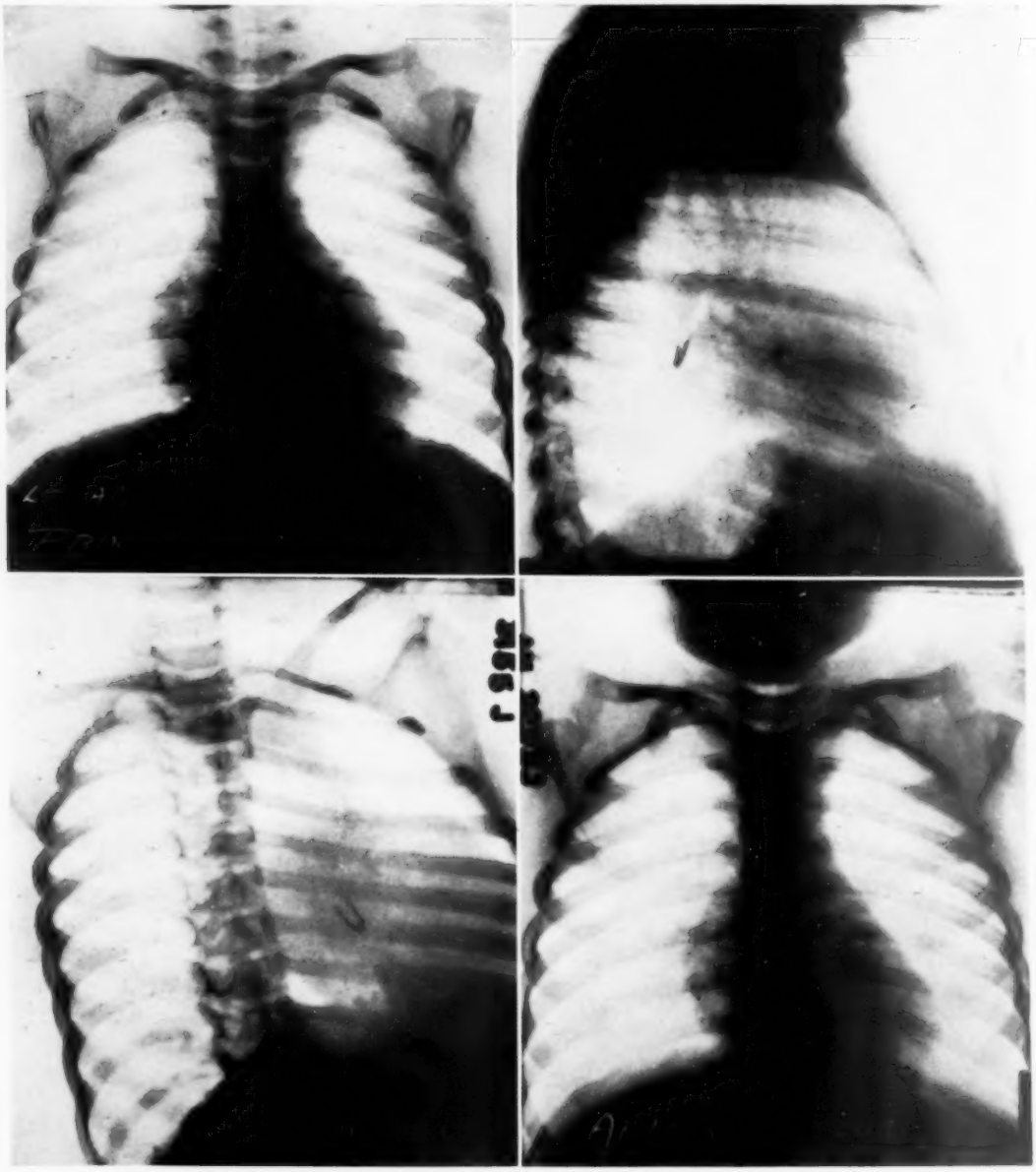

Fig. 8. A staple. The oblique view is necessary to show the maximum spread of the points.

tremely important to try to obtain a duplicate of the open safety pin that is found in the air passages. They vary in size; they vary in the shape and opening of the keeper; they vary in the size of the spring, and some of them have small metal clamps on the springs which make it difficult for certain types of forceps to grasp the spring; and there is a wide variation in the degree of rigidity of the entire pin. It is important to know whether there is any defect in the keeper, the point, or of either branch, that might interfere with closing the safety pin before removal. The extent of the opening of the pin must be measured carefully, and the proper angle of exposure to obtain this information should be determined by a very careful roentgenoscopic observation.

There have been a number of instances in which there were multiple safety pins. In one case, two large closed safety pins were linked together and lodged in the trachea. In the other multiple cases, the safety pins were in the esophagus.

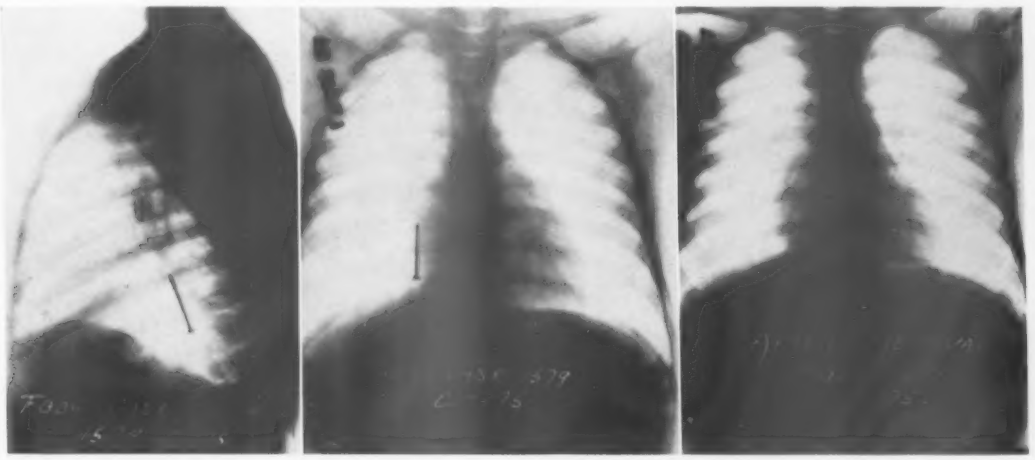

Fig. 9. A nail, head downward, in direct line with the lower lobe stem bronchus.

Fig. 10. A screw—head uppermost.

Fragments of toys and of jewelry, of irregular size and shape, require careful study and description because frequently they cannot be duplicated for external inspection.

Coins are most frequently found in the

alimentary tract but there have been a few cases of coins in the trachea and bronchi. Strangely enough, they have nearly all been cases of long sojourn—largely because it was thought that the coin was swallowed rather than aspirated into the air passages.

Pencil caps, empty shells, and other ammunition foreign bodies, present problems of interest to the bronchoscopist which sometimes can be predetermined by careful roentgenographic description.

Generally speaking, localization of bronchial foreign bodies for bronchoscopic removal is best accomplished by establishing the relation of the foreign body and its various parts to the larynx, trachea, or bronchial tree. In the larynx (Fig. 14) one can determine the level at which the foreign body is located and predetermine whether or not a pointed branch of the foreign body is imbedded in the soft tissues. Of the opaque foreign bodies, the safety pin is the

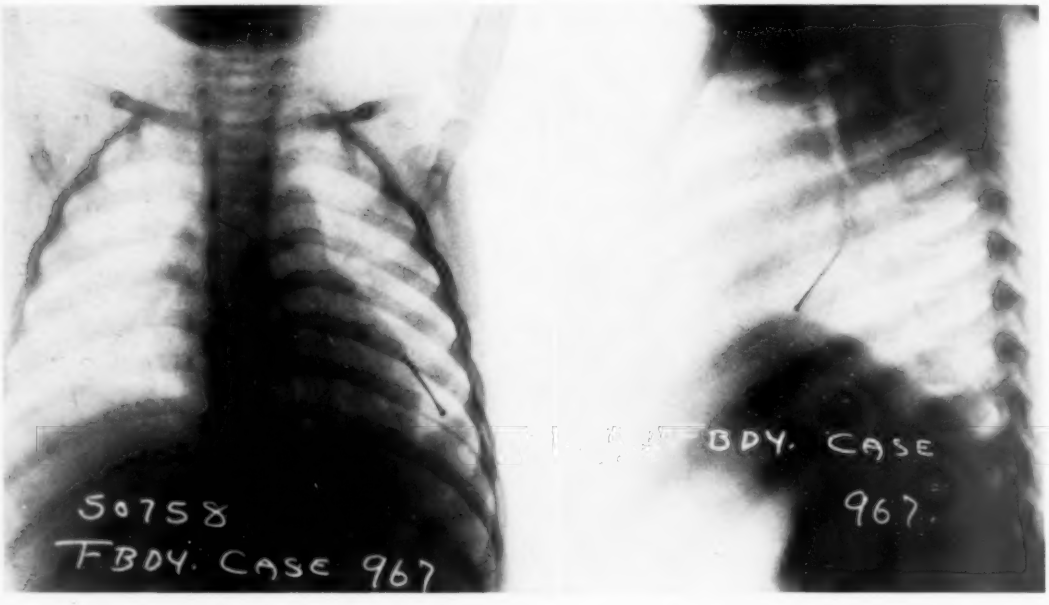

Fig. 11. A straight pin in the most anterior and external branch of the left lower lobe bronchus. The safety pin shown was in the clothing.

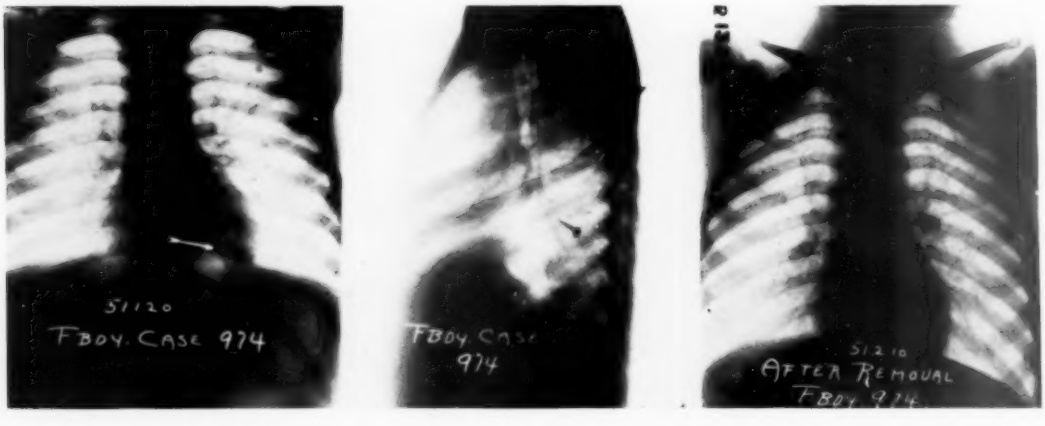

Fig. 12. Note the tack in an upper posterior branch of the left lower lobe bronchus. The point is well beyond the line of the stem bronchus.

most common one that lodges for any length of time in the larynx. In the trachea, the size and shape of the foreign body determine whether or not it will pass on into the bronchi, but, as a rule, a foreign body that can pass through the glottis can also reach the bifurcation of the trachea (Fig. 15). There have been a few exceptions to this rule. In one instance, a shawl pin lodged in the trachea just below the glottis because the point of the pin became imbedded in the anterior tracheal wall, evidently from a violent coughing effort.

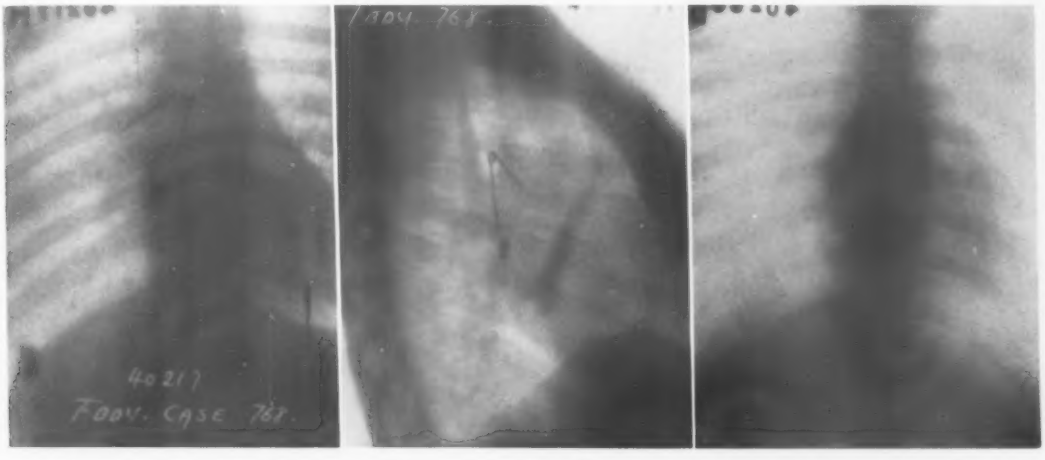

Fig. 13. Large open safety pin. The point branch is in the right upper lobe bronchus; the keeper is in the continuation of the main bronchus. Note the bluntness of the point. This safety pin must have opened after being aspirated.

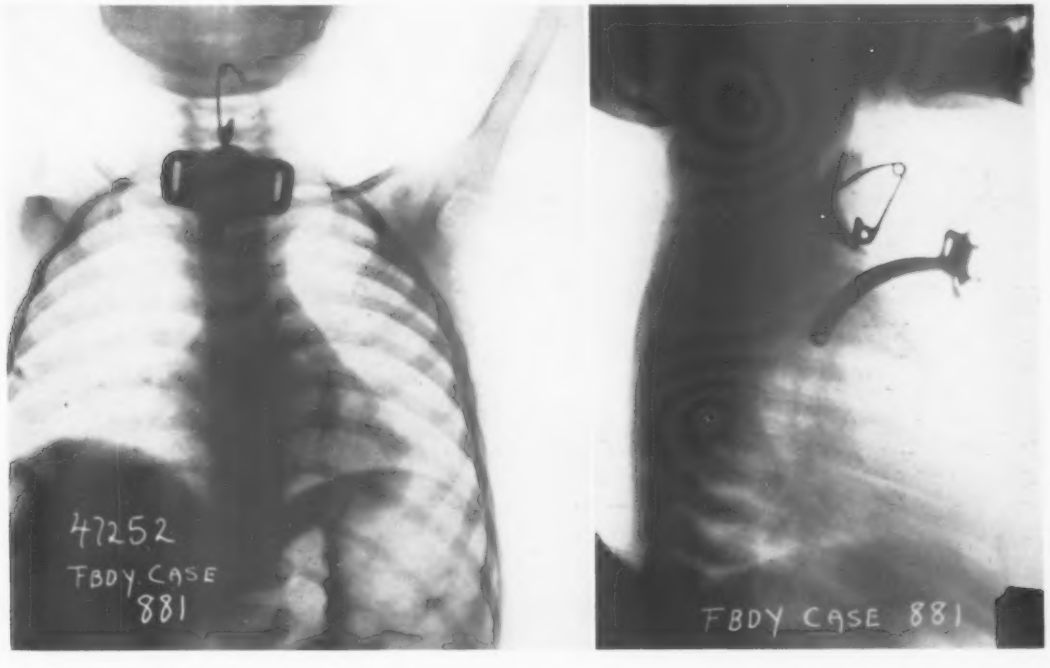

Fig. 14. Open safety pin in the larynx. Present approximately nine months. Patient thought to have enlarged thymus.

As a rule, foreign bodies in the trachea are

disposed with their flat sides presenting laterally, while in the esophagus the flat side is usually placed anteroposteriorly. But there are exceptions. Roentgenograms should be made in the anteroposterior and lateral views, and from as many other angles as are necessary to furnish a complete description of the foreign body and its distribution; but, with the anteroposterior and direct lateral views, one can determine the relation between the foreign body and the trachea, the main bronchus, or the stem bronchus. If there remains any doubt as to the location of the foreign body above the level of the bifurcation of the trachea, the patient should be given a small quantity of bismuth mixture to drink to show the relation between the esophagus and the foreign body (Fig. 16). Also, there are occasions when a small quantity of powdered bismuth subcarbonate insufflated into a bronchus through the bronchoscope will show a very definite relation between the foreign body and a particular bronchial branch, and also determine to some extent the degree of bronchial obstruction.

The localization of an opaque foreign body in the absence of any other lung pathology is a relatively simple mechanical or technical problem. The localization should be made just prior to the bronchoscopy because a definite percentage of bronchial foreign bodies shift from one bronchus to another or from one branch to another without creating any definite or increased disturbance. For instance, a tack localized in the right bronchus one afternoon was found to be in the opposite bronchus a few days later, just before bronchoscopy (Fig. 17). I have seen foreign bodies shift from one location to another while watching the patient breathe under roentgenoscopic observation, so that, if the bronchoscopic removal is to be made without the aid of the double-plane roentgenoscope, localization should be made just prior to the bronchoscopy.

Fig. 15. Open safety pin with the keeper in the larynx, the spring in the trachea, and the point imbedded in the anterior wall just below the glottis.

After lung changes develop as a result of interference with drainage and infection, then the problems of localization are more difficult and it becomes a matter of determining what particular portion of a lobe is involved in the pathologic process, in order that the bronchoscopist may know what preparation to make for bronchoscopic investigation. As I have said before, most foreign bodies remain at the site of primary impaction, at the point where they interfere with drainage, but they do at times finally become located in the extreme

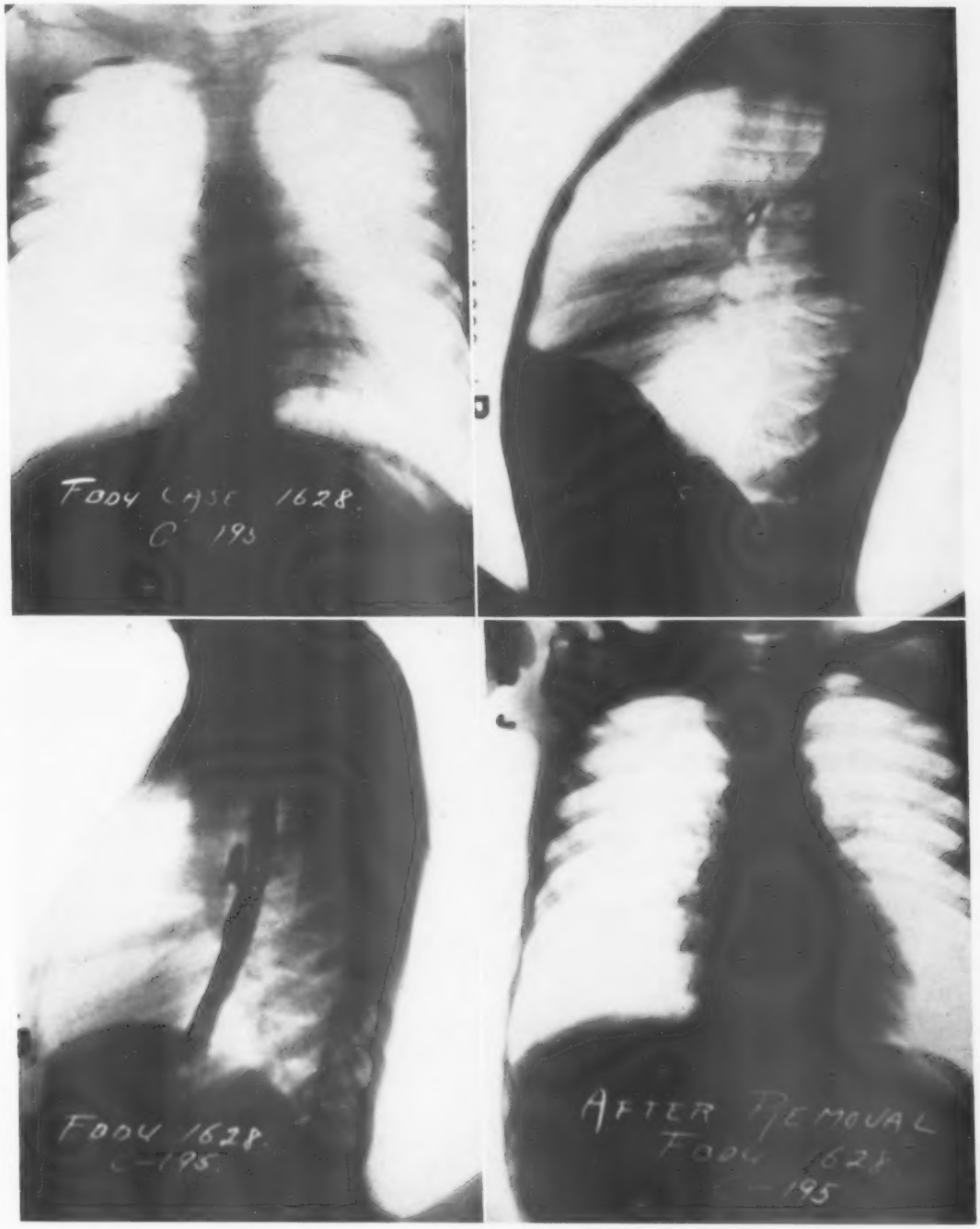

Fig. 16. A form of tin whistle—the flat side anteroposteriorly—usual presentation of esophageal foreign body. Note bismuth in esophagus, proving that foreign body is in the trachea just entering the right main bronchus.

dependent portion of the lung because of destruction of the lung tissue and the gravitation of the foreign body.

Opaque foreign bodies in dense pathologic lesions are those that are most favorable for double-plane roentgenoscopic guid-

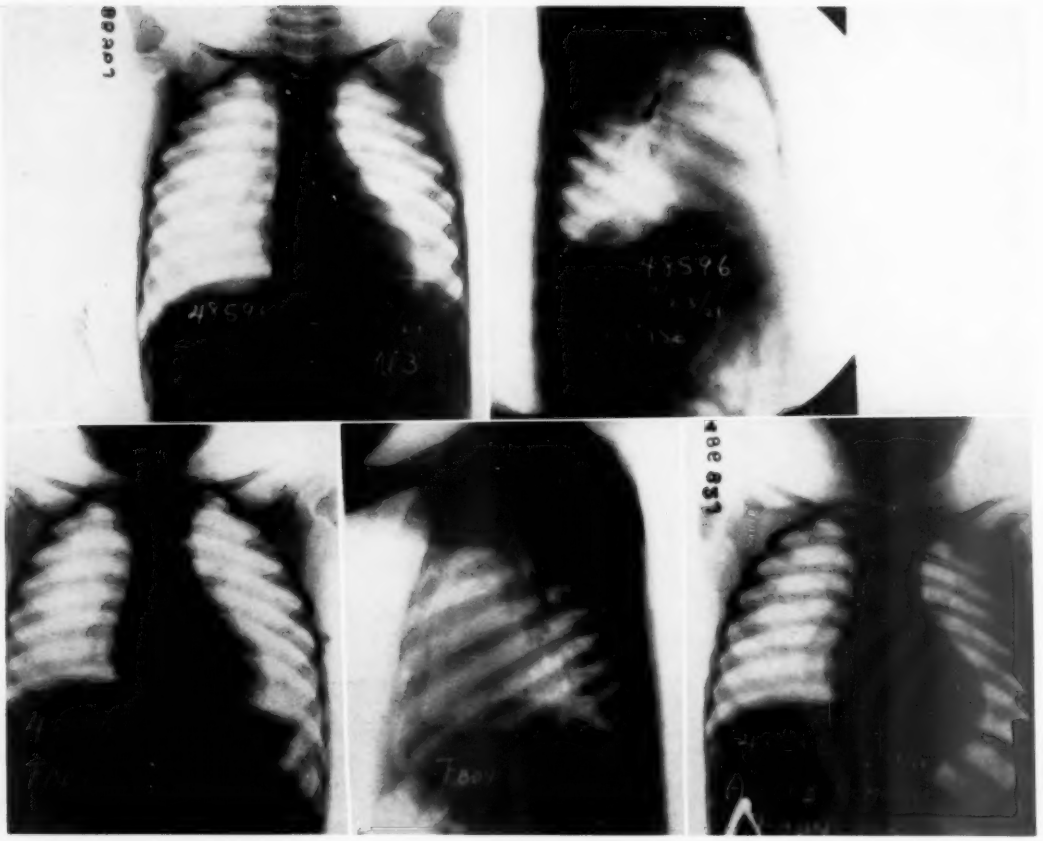

Fig. 17. Shows a tack in the left main bronchus (above) and in the right main bronchus five days later. This localization was done just before removal.

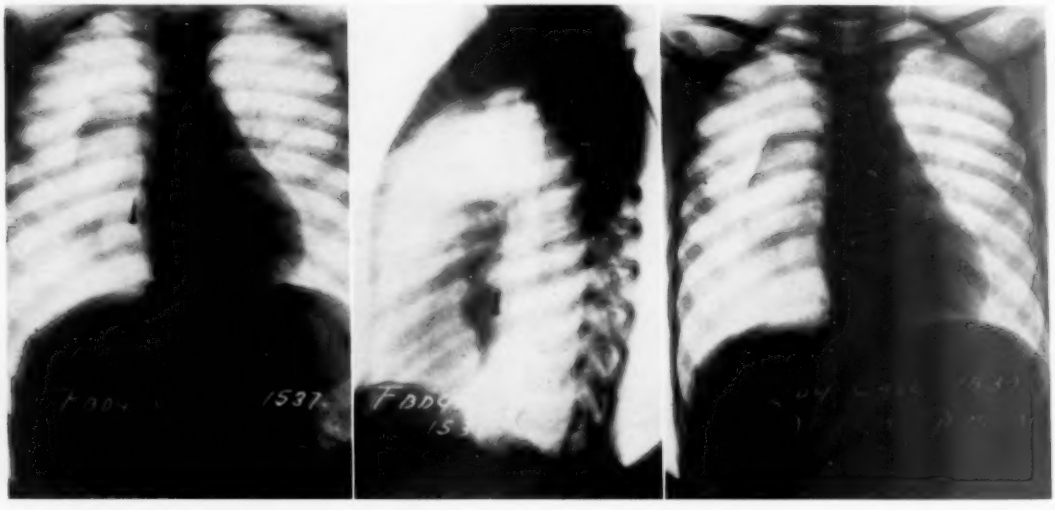

Fig. 18. A carpet tack imbedded in a completely collapsed lung. Collapse due to pneumothorax; pneumothorax due probably to puncture of interlobar pleura by the tack.

ance of the bronchoscopist in his efforts to remove the foreign body. Localization is thus accomplished roentgenoscopically at the time of the operation (Fig. 18).

Stereoscopic roentgenograms are at times valuable in helping one to discover the shadow of a foreign body that is lacking in density. I have, for instance, found roots of teeth on stereoscopic films that might have been difficult to find from a single exposure, but there is comparatively little value in the stereoscopic localization of a foreign body after it gets below the level of the bifurcation of the trachea.

Jackson has repeatedly made the observation that many of the metallic foreign bodies seem to have the property of preventing infection, and there have been a number that were present for a great many years without producing extensive damage. On the other hand, in one case, a shawl pin, present for thirty-five years, was found in the bottom of a very sharply walled off cavity which involved most of the lower lobe on the right side, and this cavity had gone through various stages of infection, granulation tissue development, fibrosis, and finally had become malignant.

Jackson has made the further observation that lung infections that result from foreign bodies (Fig. 19) are much more amenable to treatment than lung infections caused in other ways, and he has shown that with few exceptions patients with relatively extensive lung infections have recovered very satisfactorily after bronchoscopic removal of the foreign body without any other form of treatment; whereas lung abscesses or other varieties of infection are extremely difficult to control by any form of treatment. When lung changes do take place, they are the result of interference with drainage or of injury to the mucous membrane or the bronchial walls or of unsuccessful efforts at removal. In contrast to metallic objects is the tooth fragment, such as a portion of a crown or a root of a tooth, which always causes infection, and usually early and fairly extensive infection (Fig. 20). The foreign body that by its size produces marked bronchial obstruction is usually associated with more or less obstructive emphysema or with some degree of atelectasis or some degree of "drowned" lung. These conditions favor infection and ulceration. Strictures and bronchiectasis are common results. It is remarkable how the infection remains localized, even in cases of long sojourn and of extensive localized destruction. Occasionally, a pointed foreign body, such as a tack,

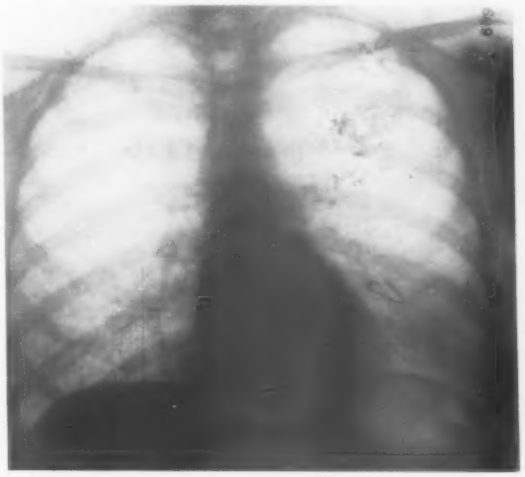

Fig. 19. A small gold pin present in the lung approximately eighteen years. There is relatively little pathologic change in the lung distal to the foreign body.

staple, or pin, penetrates a bronchial wall and even an interlobar pleura, so that there have been a few cases of extensive pneumothorax or of pyopneumothorax as a result of such injury. In most of these extensive injuries, the patients have had previous bronchoscopic examinations so that it is difficult to determine whether the trauma is due to instrumentation or to the foreign body alone.

The bronchoscopist sees the interior of the bronchial lumen and can readily determine the size of a stricture and the condition of the mucous membrane adjacent to it, and he has means whereby he can actually investigate the interior of cavities that are in direct line with the bronchoscope, but the roentgenogram is by all

means the best method of determining the extent of the pathologic process or the extent of the complicating lesion. Occasionally extensive destruction of lung tissue follows the presence of foreign body. Notably, a collar button in the left bronchus for only two years was responsible for complete destruction of the lung tissue on that side. At the present time (more than ten years after removal of the foreign body), there remains nothing of the left lung except a large number of bronchiectatic cavities and fibrous tissue (Fig. 21).

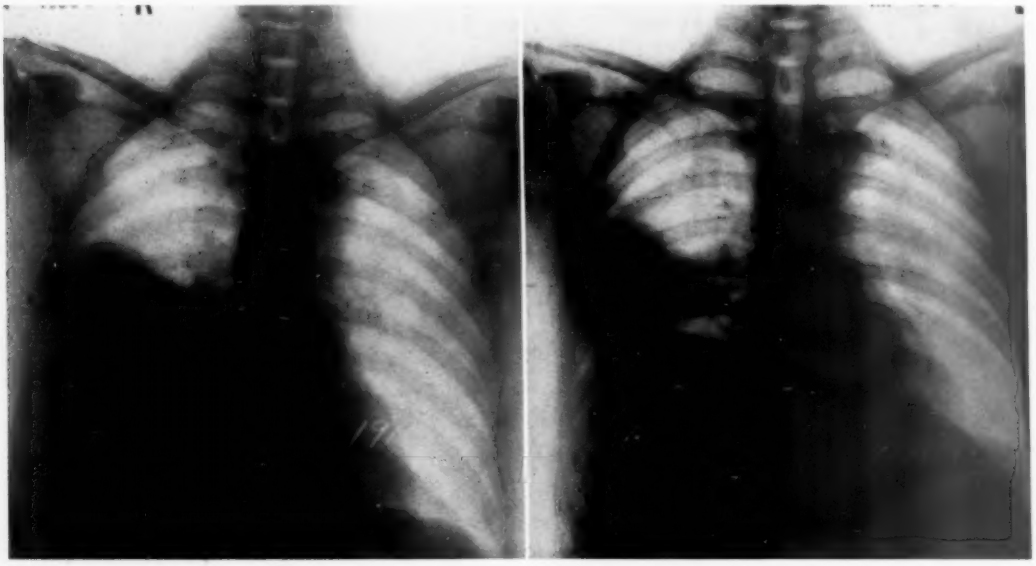

Fig. 20. Extensive amount of exudate in lung distal to a dental foreign body. Note the decrease in the amount of exudate immediately after removal and aspiration of pus.

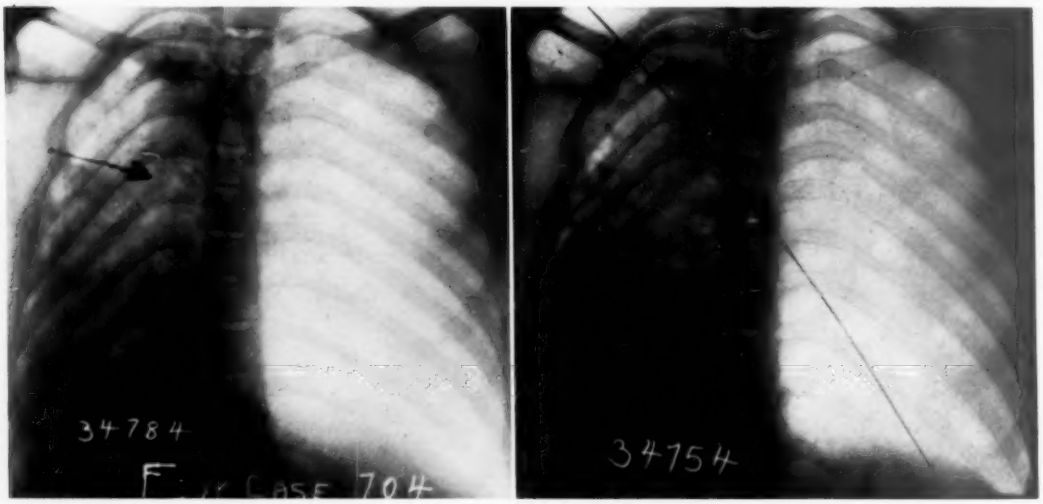

Fig. 21. Two views of a collar button present in the lung two years. There is complete destruction of the left lung. There remain only a large number of bronchiectatic cavities.

It is extremely important to make ex-

cellent roentgenograms after removal of the foreign body. They serve not only to protect the bronchoscopist in case of further accident but they come to be a very important part of the records of the case.

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THE INFERIOR ACCESSORY LOBE OF THE LUNG*

By LEO G. RIGLER, M.D., *and* LESTER G. ERICKSEN, M.D.
MINNEAPOLIS, MINNESOTA

WHILE the frequency of anomalous lobes of the lungs has been recognized by anatomists for many years, the roentgenological findings in such cases have received relatively little emphasis. The most striking example of this is the rediscovery in the roentgenogram of the azygos lobe of the right lung, although it had been well described anatomically long before. Despite the rather infrequent occurrence of this extra lobe, it appears in less than 1 per cent of cases—a large literature concerning it has now accumulated. The fact that an accessory lobe may occur at the base of either lung, much more commonly than this, has been generally overlooked by roentgenologists.

Gråberger[3] has recently called attention to the roentgenological manifestations of the basal median lobe of the lung, an accessory lobe occurring on either side, but it was first described by Rektorzik[5] in 1861. It is therefore sometimes called the inferior accessory lobe of Rektorzik. It is well known to comparative anatomists that, almost without exception, a basal lung division, often called the cardiac or retrocardiac lobe, occurs on the right side in quadrupeds. The human inferior accessory lobe appears to develop from this heart lobe of animals and is supplied by the heart bronchus. When present on the left side it is supplied by the medial branch of the second anterior bronchus.

Schaffner,[7] in 1898, examined 210 human lungs post-mortem, and found this lobe to be present, partially or entirely formed, on either the right or left sides, in 45.7 per cent of the lungs.

The incidence in the 210 lungs was as follows:

Completely formed, right side, 15 times
Completely formed, left side, 13 times
Completely formed, bilateral, 3 times
Partially formed, right side, 31 times
Partially formed, left side, 37 times
Partially formed, bilateral, 15 times

The degree of formation varies from a completely separated lobe to a mere suggestion of an interlobar fissure. If complete, the lobe will occupy from one-third to one-fifth of the inferior surface of the lower lobe and will have a fissure from 0.5 cm. to 0.2 cm. in depth surrounding it. The pleura dips into this fissure, and even though the fissure may close, the pleural reflexion often extends completely to the hilus. If the lobe is only suggested, there may be only a slight indentation or puckering where the fissure should be, with the pleura extending toward the hilus a short distance as a fibrous line. Often there may be a fairly completely formed tongue of the lateral border which fuses with the under surface of the lower lobe as it extends medially and superiorly. Between these three types, there are, as has been said, all possible transitions. Figure 1 is a photograph of a fairly typical, well-formed inferior accessory lobe on the right side, found by Dr. R. Koucky at post-mortem examination of a young child in the University Hospital.

The roentgenological manifestations of this lobe were not recognized until the recent work of Gråberger who described the appearance which it produces in connection with the differential diagnosis of basal paramediastinal shadows. He reported 2 cases from the Anatomical Institute at the University of Upsala and 9 cases in which the lobe was discovered in the roentgenogram. He described a fine, thread-like, dense line running from a small tent on the medial portion of the diaphragm, medially and upward toward the hilus of the lung. The line may be lost in the lung parenchyma a short distance above the diaphragm (Fig. 2).

* From the Departments of Radiology of the University of Minnesota and the University Hospital, Minneapolis, Minnesota. Presented before the Minnesota Radiological Society, Feb. 13, 1932.

Fig. 1. Photograph of lung of infant removed at autopsy. The medial surface of the lung is shown. The inferior accessory lobe is shown near the inferior surface projecting like a tongue. The interlobar fissures of this lobe are indicated by arrows.

Fig. 2. Roentgenogram of lower half of right lung demonstrating fine linear density extending from small diaphragmatic "tent" (arrow) upward and medially toward the hilus. This is the characteristic appearance of the interlobar pleura of the inferior accessory lobe.

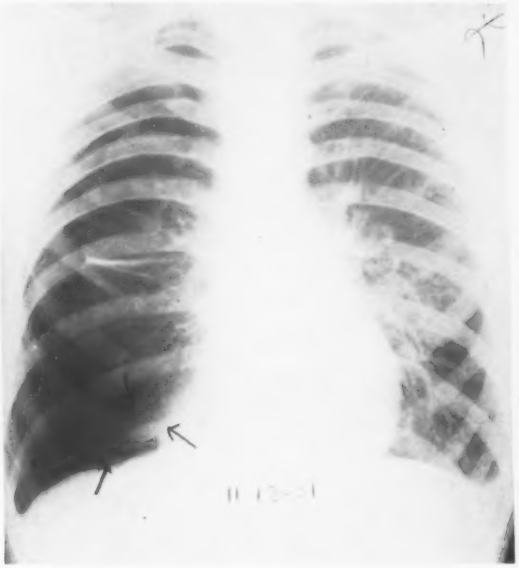

Fig. 3. Spontaneous pneumothorax, right, showing four lobes. Note the visualization of the interlobar fissures, the minor fissure being sealed. The main fissure is shown below that. Near the base the fissure between the lower lobe and the inferior accessory lobe is visualized. The latter is shown (arrows) as a tongue-shaped division with its point over the diaphragm.

We have been fortunate enough to observe this accessory lobe, clearly defined, in a case of pneumothorax. This was in a patient in the Students Health Service of the University of Minnesota, who developed a bilateral spontaneous pneumothorax with complete collapse of the lung on the right side. Roentgenographic examination during the course of the recovery (Fig. 3) revealed four clearly defined lobes on the right side, one giving a small, triangular-shaped shadow at the base on the mediastinal side. Our interest having been aroused by this finding, we have pursued the matter further. We have since succeeded, with the cooperation of the Pathology Department, in demonstrating this lobe 3 times in 11 autopsies. We have also been able to demonstrate conclusively that the shadow described by Gråberger, as shown in Figure 2, is actually due to the interlobar line of this basal median lobe.

Laurell[1] has repeatedly stated that the di-

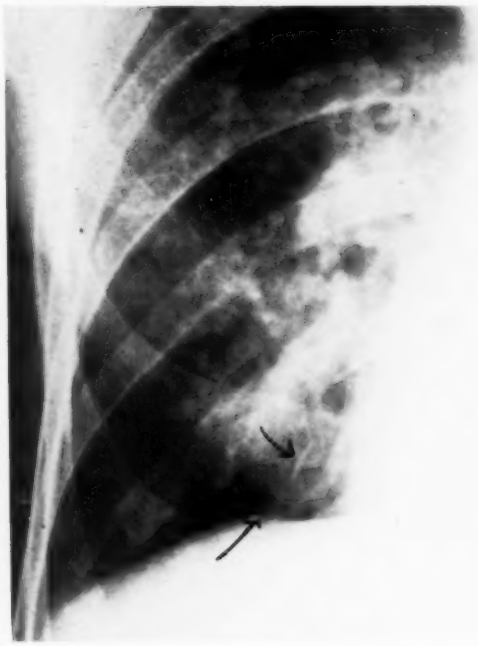

FIG. 4*a*. Roentgenogram of right lung showing fine line at base representing interlobar fissure of inferior accessory lobe (arrow).

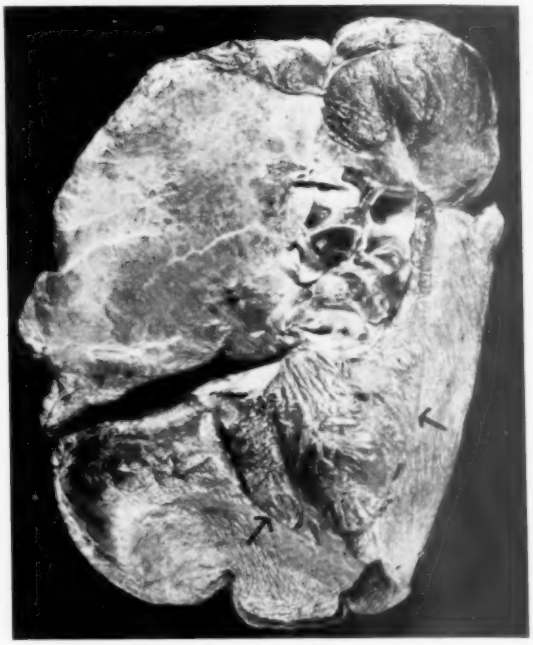

FIG. 4*b*. Photograph of lung from same case removed at autopsy. The medial surface of the lung is shown with the inferior accessory lobe in its inferior portion (arrows). The appearance is similar to that in Figure 1.

aphragmatic "tents" which are so frequently observed are actually extensions from the diaphragm into the interlobar fissures. Rarely this can be clearly demonstrated by the observation of a dense line running from the diaphragmatic irregularity upward and laterally, taking the characteristic course of the main interlobar fissure. It is more difficult to explain those "tents" which occur in the medial third of the diaphragm unless their connection with the interlobar fissure of an inferior accessory lobe is assumed. Our observations have confirmed this theory advanced by Gråberger, as we have been enabled in 2 cases to examine the lung post-mortem, after observing this medial tent formation with the dense line extending upward and medially from it. In both cases this proved to be due to the interlobar fissure of an extra lobe. One such case is illustrated in Figure 4.

To further demonstrate the correctness of this observation, we have made roentgenograms of the lung, illustrated in Figure 4*b*, after the interlobar fissures were all painted with a barium vaseline paste, or covered with lead foil, and the result is shown in Figure 5. This being the right lung, the usual two large fissures are well shown. In addition, in the posteroanterior view (Fig. 5*a*), a third fissure is demonstrated extending from the inferior surface of the lower lobe inward and upward toward the lung hilus. This dense line has exactly the position and form of that described above (Figs. 2 and 4*a*) and indicates conclusively the origin of this shadow. The position of the fissure on the lateral aspect of the lung is shown in Figure 5*b*.

The interlobar pleura, when thickened or containing small quantities of fluid, will usually be clearly demonstrable on a roentgenogram if it is in such a position as to be struck somewhat tangentially by the rays. As a matter of fact, a normal interlobar fissure may produce a fine, hair-line shadow if the direction of the rays applied is such as

to strike it in a completely tangential way. Thus, in normal individuals, the minor interlobar fissure on the right can frequently be seen in the posteroanterior roentgenogram, while the main fissure is occasionally seen in the lateral view. The interlobar fissure of the azygos lobe is seen more constantly, probably because of the large vein running through it. The interlobar fissure of the inferior accessory lobe has an almost straight anteroposterior direction. In anteroposterior or posteroanterior exposures, therefore, it is very likely to be struck tangentially by the roentgen rays with a resultant visualization of the pleura in a very high percentage of the cases in which it is present, even though it is normal.

Fig. 5*a*. Roentgenogram (retouched) in posteroanterior view of lung removed from body of same case as shown in Figure 4. Barium has been placed in the interlobar fissures. Note the position of the minor fissure above, the main fissure below, and the fissure (arrows) of the inferior accessory lobe which appears to cross the oblique fissure. Note the similarity in form and density to the roentgenograms shown in Figure 2 and Fig. 4*a*.

Fig. 5*b*. Same lung in lateral view. Lead foil has been placed in the interlobar fissures, and the anteroposterior direction of the fissure (arrows) of the inferior accessory lobe is well shown.

If this interlobar pleura extends completely up to the hilus, it will come into a more horizontal plane in its upper portion. This portion may therefore be struck tangentially in the lateral view and it may be possible to visualize it in roentgenograms made under these conditions. This would only be true if the lobe were completely formed and rather large. The shadow observed would be a line extending from the posterior margin of the lung anteriorly to meet the main interlobar fissure, and such a case is illustrated in Figure 6. While we have been unable to confirm definitely that this shadow is due to such a formation, it seems highly probable.

FIG. 6. Roentgenogram of lungs in right lateral view. A transverse fine linear shadow (arrows) can be seen extending from the posterior chest wall to meet the main interlobar fissure in front. This shadow is similar to that of the minor fissure except that the latter always lies anterior to the main fissure. In this case an inferior accessory lobe could be clearly made out in the posteroanterior view and it seems probable that this is the lateral view of the fissure of a well-formed inferior accessory lobe.

We have investigated an unselected group of roentgenograms of the chest with careful observation of the bases of both lungs to determine the presence of this unique shadow. In 500 cases, this interlobar line was clearly recognizable in 8.2 per cent. It was present 33 times on the right (as illustrated in Fig. 7), 5 times on the left (as illustrated in Fig. 8), and 3 times bilaterally (as illustrated in Fig. 9). When it is considered that the line on the left is hidden effectively by the shadow of the heart, the discrepancy between these figures and those of Schaffner is readily understood. When it is further considered that many of the cases, no doubt, give no shadow because the interlobar fissure is not well developed, but simply suggested, because the

FIG. 7. Roentgenogram of chest showing typical appearance of large inferior accessory lobe on the left. Note the very fine hair-line shadow (arrows) extending from the diaphragmatic tent. This lobe was sufficiently large to carry the shadow of the fissure well beyond the heart shadow, thus making it visible.

FIG. 8. Roentgenogram of chest showing typical appearance of large inferior accessory lobe on the right side. Note interlobar pleural shadow of this lobe (arrows) which can be followed practically to the hilus indicating a rather well-formed lobe.

pleura is not thickened, and because the direction of the fissure may be such that it is not struck tangentially by the beam of roentgen rays, the discrepancy between the incidence of this lobe as demonstrated anatomically, and that as demonstrated roentgenologically can be well understood. In spite of these handicaps, this shadow is present in recognizable form at least eight times as frequently as that of the azygos lobe. In 2 cases, the interlobar fissure of both the azygos lobe and the inferior accessory lobe was observed on the right side, thus indicating the presence of five lobes in the right lung (Fig. 10).

Aside from the interest in determining the cause and incidence of this shadow in roentgenograms of the lungs, the demonstration of its presence is important in the differential diagnosis of basal paramediastinal shadows in general. The differentiation of this interlobar pleural shadow from

Fig. 9. Roentgenogram of chest showing bilateral inferior accessory lobes. The one on the right is well formed and very obvious (arrows). Note the diaphragmatic "tent" from which the interlobar pleura seems to arise. On the left the shadow of the interlobar pleura (arrows) can just be seen through the heart shadow.

Fig. 10. Roentgenogram of chest showing azygos lobe and inferior accessory lobe on the right side. There are, therefore, five lobes in the right lung. Note clear shadow of interlobar pleura (arrows), of azygos lobe at apex and of inferior accessory lobe (arrows) at base. The latter is shown only just above the diaphragm.

other structures in this region, if the accessory lobe is normal, presents no great difficulties. Occasionally, a pneumothorax may occur in which the lung is separated from the diaphragm in such a way as to permit the mediastinal or diaphragmatic pleura to be visualized (Fig. 11). This may simulate the interlobar pleural shadow of this extra lobe, but a comparison of Figure 11 with Figure 2, in which the shadow of the interlobar pleura is really present, reveals the distinction at once. Pleurodiaphragmatic and pericardio-diaphragmatic adhesions might also simulate it but the distinction is not difficult.

A triangular-shaped shadow, with its apex at the cardiophrenic angle and its base extending from the hilus above to the middle portion of the diaphragm below is occasionally met with in roentgenograms of the chest. Most frequently this is due to an encapsulated effusion in the mediastinal portion of the pleura (Fig. 12), as reported by Sagel and Rigler,[6] and many others.

FIG. 11. Roentgenogram of portion of right lung with pneumothorax. The lung is collapsed on its lateral and inferior surfaces so that the shadow of the diaphragmatic pleura can be visualized (arrows). This might readily simulate the interlobar pleura of an inferior accessory lobe.

Atelectasis of a portion or the whole of the lower lobe, infiltration of the medial portion of the lower lobe such as occurs with tuberculosis, chronic pneumonitis, or bronchiectasis, may also produce a similar shadow. As has been reported by Assmann,[1] Ettig,[2] and Gråberger,[3] consolidations or infiltrations of the accessory lobe must also be considered as a probable source of such a shadow. An illustrative case is shown in Figure 13. This patient had all the clinical signs of pneumonia with only the small consolidation in the right cardiophrenic angle demonstrable in the roentgenogram. The sharp outlines of this density suggest strongly that it is not simply a small patch in the lower lobe, but rather that it is a lobar consolidation involving a separate lobe in this region. Re-examination later revealed a complete disappearance of this shadow. Gråberger reports 4 such cases, in all of which the distinction from an encapsulated mediastinal pleural effusion was made with difficulty. Ettig and Assmann also report similar cases which were discovered at autopsy.

An opposite type of case is illustrated in Figure 14. In this instance there were the typical clinical signs of lobar pneumonia, but the roentgen findings were distinguished by the very sharp medial border of the shadow in the right lower lobe. Otherwise the appearance was characteristic of a right lower lobe pneumonia. The absence of any shadow in this medial angle is very unusual in lower lobe pneumonia, but may readily be explained by the presence of an accessory lobe, whose interlobar pleura limits sharply the medial border of the consolidation, the accessory lobe itself remaining normal. A realization of this possibility may help in some cases to explain an unusual distribution of the shadow of a lower lobe pneumonia.

It seems probable that many cases in which a shadow is found in the region of the cardiophrenic angle and in which the lateral border is very sharp and straight, which have been diagnosed as localized bronchiectasis or unresolved pneumonia of the lower lobe, may in reality have been

FIG. 12. Roentgenogram showing encapsulated mediastino-interlobar effusion on right (arrows). This shadow corresponds well to the limits of the inferior accessory lobe and a consolidation of the latter might give a similar finding.

infiltrations of this accessory lobe. The differential diagnosis of these conditions is likely to be difficult. Gråberger[3] and Schönfeld[8] have dealt with it in great detail. The former believes that the curve of the outer border of the triangle will make the distinction. A consolidated or infiltrated basal median accessory lobe should have a straight border; an encapsulated mediastinal pleural effusion should have a rounded border with the convexity directed outward; an atelectatic lower lobe or a fibrous mediastinal pleurisy should have a rounded, concave, outer border. This distinction may be helpful but certainly does not always apply. Examination in the lateral view may occasionally reveal the mediastinal pleural fluid more clearly. Observation with repeated examinations may be more helpful. Acute consolidation of the accessory lobe will clear up very rapidly as reported in the case illustrated in Figure 13, while the other conditions mentioned remain for much longer periods of time. In the case of atelectasis of the whole lower lobe the secondary effects such as retraction of the heart, mediastinum, and diaphragm are also helpful in making this distinction. Paracentesis of the posterior mediastinal space usually reveals fluid in the cases of encapsulated effusion, and may thus aid in the differentiation. Roentgenoscopic and roentgenographic study in various positions is often of great importance.

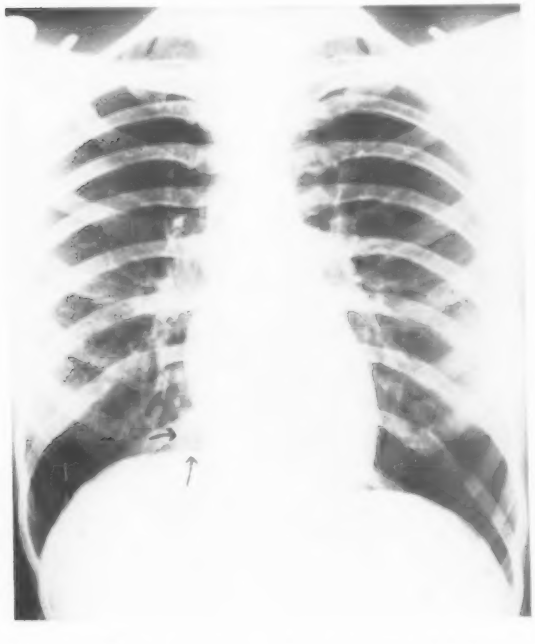

Fig. 13. Roentgenogram showing consolidation of small inferior accessory lobe on right (arrows). The patient had symptoms of pneumonia and this was the only shadow observed. This disappeared completely within a short period of time.

Fig. 14. Anteroposterior roentgenogram of right lower lung in a case of right lower lobe pneumonia without involvement of the inferior accessory lobe. Note the characteristic density of the lower lobe with its hazy upper border. The medial border (arrows) is very sharp and corresponds well to the position of the interlobar fissure between the lower lobe and the inferior accessory lobe. The latter is not involved in the pneumonic process and shows a normal air content.

Numerous other causes for a shadow in this region may occur. The inferior vena cava may give a very small shadow in the cardiophrenic angle but is easily recognized. The extension of the pericardium into this region is also diagnosed without difficulty. Paravertebral abscess, aneurysm of the descending aorta, paraesophageal

hernia of the stomach, esophageal dilatations, and mediastinal tumors can all be excluded with ease, if the roentgenologic features which distinguish each of these conditions are borne in mind. The exact appearance of the inferior accessory lobe, either in its normal state or when affected by some pathologic process, is sufficiently characteristic so that it may be easily recognized after it has once been observed. Its presence must be strongly considered in the differential diagnosis of shadows in the medial portion of the base of the lung.

SUMMARY AND CONCLUSIONS

An accessory lobe at the base of either lung has previously been demonstrated anatomically to be present, either partially or completely formed, in 45.6 per cent of 210 lungs. This lobe is of variable size and development and represents a division of the lower lobe.

In roentgenograms of normal lungs a fine linear shadow may occasionally be seen extending from the medial portion of the diaphragm upward and medially toward the hilus of the lung. This represents the interlobar pleura of this inferior accessory lobe.

In 500 unselected cases this shadow could be distinctly made out on either side or on both in 8.2 per cent. In two cases the azygos lobe and the inferior accessory lobe were both present in the right lung.

Two cases presenting this shadow in the roentgenograms of the chest were observed later at autopsy and the presence of this extra lobe confirmed. The identity of the shadow observed with the interlobar pleura of the inferior accessory lobe was established by post-mortem roentgen studies of the lungs.

Infiltration of this lobe may occur and a case of lobar pneumonia involving this lobe alone was observed.

In the differential diagnosis of shadows in the base of either lung or near the mediastinum, this extra lobe must be strongly considered. It may be very difficult to distinguish encapsulated mediastinal pleural effusions from infiltrations of this lobe.

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MULTIPLE TUMOR IMPLANTS IN THE VENTRICLES REVEALED BY VENTRICULOGRAPHY

REPORT OF CASE

By JAMES R. LEARMONTH, Ch.M., F.R.C.S. (Ed.),
Section on Neurologic Surgery
and
JOHN D. CAMP, M.D.,
Section on Roentgenology
THE MAYO CLINIC, ROCHESTER, MINNESOTA

IN THE case reported here we were able, although unfortunately only after necropsy, to detect the presence of ventricular tumor implants in the ventriculograms. As such implants are not uncommon, we hope that this report may draw attention to the possibility of diagnosing them, and so avoiding an unavailing major surgical procedure.

The patient, a man, aged twenty-nine, came to The Mayo Clinic, April 12, 1932. Since December, 1931, he had been out of sorts, with mild frontal headaches, tiredness, and giddiness. In January, 1932, the headaches and vomiting became severe, the vertigo was marked, and the gait staggering. At the same time vision began to fail.

Except for incoördination and staggering gait, objective neurologic signs were absent. The original roentgenograms of the skull revealed evidence of increased intracranial pressure, erosion of the anterior and posterior clinoid processes and thinning of the orbital plates of the frontal bone. These observations were not of definite localizing value. Vision was 6/20 in the right eye and 3/60 in the left; both optic discs were swollen to 6 diopters; perimetry revealed bilateral cecocentral scotomas.

As the ophthalmologic signs pointed to the presence of a prechiasmal lesion, whereas the clinical signs were cerebellar, ventriculography was performed for purposes of localization. The ventriculograms revealed internal hydrocephalus and dilatation of the third ventricle. There was an obvious rounded filling defect in the floor of the third ventricle and a lobulated defect in the inferior portion of the anterior horn of each lateral ventricle. The unusual nature of the deformities was appreciated, but in an effort to explain them on the basis of a single lesion, a diagnosis was made of a basofrontal tumor extending to and involving the floor of the third ventricle.

On April 20 the chiasmal region was explored. No obvious tumor could be detected, and the operation was difficult because ventricular puncture was followed by brisk hemorrhage into the ventricle. Three days later the patient died.

At necropsy a mass filling the fourth ventricle was found. This had extended upward through the aqueduct of Sylvius, surrounded the pineal gland, and implanted itself in numerous areas in the floor of the third ventricle and in the walls of the lateral ventricles, which had a papillomatous appearance. It had grown through the floor of the third ventricle and had surrounded and infiltrated the optic nerves and optic chiasm. There were also many implants on the surface of the brain. Microscopically, the tumor was a medulloblastoma.

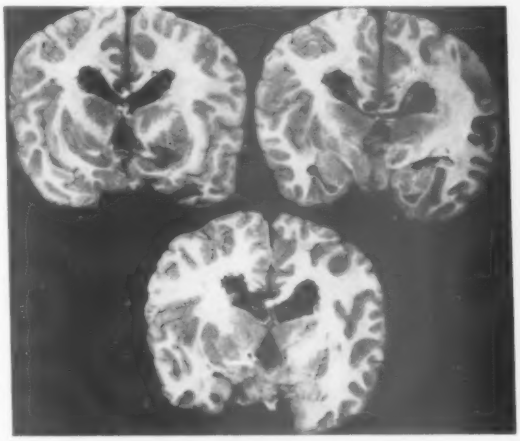

Fig. 1. Coronal sections through the brain, showing the lesion in the floor of the third ventricle and in the optic chiasm, and the pedunculated tumor implants on the walls of both lateral ventricles.

When the ventriculograms were reviewed in the light of the changes observed at necropsy the reason for the distribution

FIG. 2. Ventriculogram in lateral position, showing shadows of tumor implants in lateral and third ventricles.

and nature of the defects was readily apparent. The multiple tumor implants on the floor of the anterior horns and in the third ventricle had stood in relief against the air-filled ventricles, producing the rounded and lobulated defects noted. In addition, rounded defects in the shadow of the floor of the inferior horns, the importance of which was not recognized, proved to be tumor implants.

As far as we know, the possibility of diagnosing tumor implants in the ventricles by means of ventriculography has not been described in the literature. Inasmuch as this condition is not uncommon, the findings in this case will serve to emphasize the importance of considering multiple lesions when a ventriculogram reveals more than one filling defect.

FIG. 3. Ventriculogram in anteroposterior position, showing shadows of tumor implants in lateral and third ventricles.

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ENCEPHALOGRAPHY IN A CASE OF LOCALIZED SUBCORTICAL HEMORRHAGE

By FREDERIC SCHREIBER, M.D.
DETROIT, MICHIGAN

ENCEPHALOGRAPHY has been especially useful in those cases of head injury where it is clinically difficult to distinguish between hysteria, malingering, and a definite organic lesion. The diagnosis in the following case offered these difficulties, and it seemed of sufficient interest to warrant reporting, since the roentgen findings were confirmed at autopsy some time after the diagnostic encephalograms were made.

CASE 1. *Harper Hospital Nos. 59351, 60018. Head trauma; short period of unconsciousness; frequent convulsions of right face preceded by aphasia; encephalography, revealing cyst in left hemisphere; trephine, exposing hemorrhagic area in arachnoid; autopsy finding of left subcortical hemorrhage.*

A right-handed, white carpenter, aged forty, referred by Dr. Grover Penberthy, was admitted to the Hospital January 19, 1931, complaining of attacks of aphasia, associated with involuntary contractions of the right facial muscles.

Clinical History. In July, 1929, the patient was struck on the head by an iron door track. There was loss of consciousness for twenty minutes and when the patient came to, he noticed a twitching of the muscles on the right side of the face. He was taken to a hospital, where all findings were negative, including films of the skull, and he was discharged after five days. After a few days at home, he returned to work, apparently feeling no ill effects from his accident except frequent frontal headaches. He worked for two months until one day while at work he became aware of a bursting headache, followed by an inability to speak and finally by continued twitching of the right side of his face. The whole episode lasted fifteen minutes and the patient was in a daze throughout this time, remembering nothing that was going on about him. After this spell the patient felt very tired. He had not fallen, nor was there a twitching of any muscles other than those of the right side of the face.

From this time on, a similar attack came on every seven to ten days and the patient had to give up his work. He had frequent neurological examinations which were always entirely negative and it was the impression of the neurological consultant that the man had a post-traumatic functional disturbance rather than an organic lesion. Suggestive therapy, however, was of no avail, and the attacks becoming more frequent, the patient was sent to me for encephalographic studies.

Encephalography. On January 21, 1931, lumbar puncture was done. The spinal fluid pressure in the prone position was 100 mm. (water manometer). The patient was set up, 120 c.c. of spinal fluid being allowed to escape and 100 c.c. of air injected in 5 c.c. amounts. Encephalograms were immediately made.

FIG. 1. Left lateral position showing cyst apparently above normal ventricle.

The roentgen interpretation (Figs. 1 and 2) reads: "Films were taken of the patient's skull after the removal of 120 c.c. of fluid and the introduction of 100 c.c. of air. The films show the outlining of the ventricles, all of which are normal in size and contour. There is definite evidence of a small cyst-like area in the left central region. There is, we think, some cortical atrophy shown by the increase of the air content in the sulci of the parietal regions, especially the left."

The patient made an uneventful recovery fol-

lowing air injection, and was discharged from the hospital on the third day following encephalography, being advised to return later for an exploratory trephine if the attacks continued.

Second Admission. On February 3, 1931, the patient was again admitted, having had, in the interim, several attacks of aphasia with twitching of the right face. On February 6, 1931, I

Fig. 2. Anteroposterior position, showing cyst apparently communicating with left lateral ventricle.

turned down a left central osteoplastic flap under local anesthesia. In the lower anterior region of the exposure, corresponding to the face area, there was an area 2 cm. in diameter, in which the cortex was of a wine red color. Overlying this, the arachnoid was grayish and thickened, containing a few small white plaques. The arachnoid was incised in this region and the underlying pial layer also had a peculiar grayish appearance. No frank cyst was seen, although I believed that a localized collection of fluid over the hemorrhagic cortex in this region was possible, from the appearance of localized arachnoiditis. Wound closed with replacement of flap.

The patient made an apparently uneventful recovery for two weeks following the operation, although he had several spells of aphasia followed by twitching of the right face as previously. On the fourteenth day, however, he developed signs of meningitis and died three days later with a terminal temperature of 105° F. and marked neck rigidity.

Post-mortem Findings. The brain was removed and hardened for two weeks. The immediate cause of death was a leptomeningitis. On sectioning the hardened brain, a small, localized, well-organized hemorrhage was found, corresponding to the left face area. Communicating with the subarachnoid space was a degenerative cystic space about 2.5×1 cm. (Fig. 3) which corresponded to the cyst shown in the encephalograms and the localized arachnoiditis formed at operation.

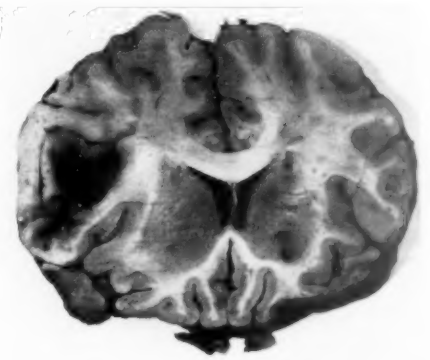

Fig. 3. Organized subcortical hemorrhage with degenerative cystic space in left face area, communicating with subarachnoid space.

Comment. From the post-mortem findings, it is obvious that in a degenerative cyst of this kind, which is the result of localized encephalotrophy due to subcortical hemorrhage, and which communicates with the subarachnoid space, nothing is to be gained by surgical intervention. This case is therefore presented in the hope that it may aid in a more limiting interpretation of encephalographic cysts, so that the operable cysts can be more readily distinguished from those in which surgery is futile.

Summary. A case of localized subcortical hemorrhage in the right face center with a correlation of encephalographic and post-mortem findings.

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Thirty-fourth Annual Meeting: Chicago, Ill., Sept. 25–30, 1933.

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Eighteenth Annual Meeting: Chicago, Ill., Sept., 25–30, 1933.

EDITORIALS

THE ROENTGENOLOGIC EXAMINATION OF THE BREAST

IT IS sometimes disconcerting to hear the statement made that unfortunately the roentgenogram will not reveal soft tissue changes. Such a statement carries with it both a lack of knowledge of roentgenographic technique and of the roentgen literature. Since the early days of roentgenology the demonstration of soft tissue shadows has been an accomplished fact, and in 1924 Sutherland[1] gave an account of the roentgenologic study of soft tissue tumors in which he reviewed 103 such tumors, among which number 62 were benign and 41 malignant. These benign tumors included such a range of shadow-casting material as the ordinary collection of pus in soft tissues to the more densely calcified tuberculous glands, and of the malignant tumors which he was able to demonstrate, 31 out of 41 were sarcomas. This study of Sutherland's was of value in establishing certain fundamental points in the differential diagnosis of soft tissue tumors.

More recently Warren,[2] Lockwood,[3] and Reimann and Seabold,[4] have considerably advanced the study of soft tissue tumors in their roentgenologic studies of the breast. Warren's first report in 1930, from the Strong Memorial Hospital, called attention to the simplicity of the method of studying breast tumors by stereoscopic roentgenograms and he evolved such a simple technique that one is able to follow it routinely in the roentgen-ray department. By this technique one is enabled to demonstrate not only the initial breast tumor but also its axillary glandular metastases, if they be present. In his original communication Warren called attention to the necessity of a knowledge of the ordinary physiologic changes that take place in the female breast during the menstrual cycle, pregnancy, and lactation, and emphasized the fact that roentgenograms of the normal breast conform to the anatomical structures which are present, whether the breast be of the obese or atrophic type; also that abnormalities visible in the pathologic breast resemble closely the gross appearance of such abnormalities and that the roentgen appearance of the various types of tumors both malignant and benign resembles the gross appearance closely enough to be characteristic of individual types of tumors.

Lockwood in a recent article calls attention to the roentgen study of the breast in the evaluation of breast symptoms and states that by this simple method the pathological state responsible for any of the cardinal presenting breast symptoms—tumor, pain, or discharge from the nipple—can often be recognized without exploratory section and that the need for biopsy can be reduced in many tumors that are clinically only suspicious but prove to be roentgenologically characteristic. He calls attention to some limitations of the roentgen examination which are shared by any method of gross observation, namely, the inability to recognize (*a*) microscopic areas of cancer, (*b*) early malignant degeneration in benign tumors and (*c*) early carcinoma associated with chronic cystic mastitis. But such early changes as these can only be recognized by microscopic study and the roentgen method

[1] Sutherland, C. G. A radiologic study of soft-tissue tumors. *Radiology*, 1924, *3*, 420–424.

[2] Warren, S. L. A roentgenologic study of the breast. Am. J. Roentgenol. & Rad. Therapy, 1930, *24*, 113–124.

[3] Lockwood, I. H. The roentgen-ray evaluation of breast symptoms. Am. J. Roentgenol. & Rad. Therapy, February, 1933, *29*, 145–155.

[4] Reimann, S. P., and Seabold, P. S. Correlation of x-ray picture with histology in certain breast lesions. *Am. J. Cancer*, January, 1933, *17*, 34–41.

is far superior to any known gross method of examination as it obviates to a large degree the necessity of repeated palpation of the breast and the axillary glands, the dangers of which have only recently been called attention to by Holman.[5]

That the roentgen examination of breast tumors in the hands of the experienced roentgenologist is capable of considerable diagnostic accuracy is emphasized by the first report of Warren in which he was able to show a diagnostic accuracy of 85 to 95 per cent. Not only does the roentgen examination of the breast offer an additional aid in the diagnosis of obscure breast tumors but it is of particular aid in those patients who have large breasts in which palpation and the usual methods of examination are not wholly satisfactory. As Lockwood says, "The roentgen examination is not offered as a substitute for other methods but as a valuable and accurate addition to the present methods for the recognition of cancer as well as other diseases of the breast." Its more widespread use would, we believe, lead to earlier recognition of breast tumors and since the ultimate cure of carcinoma of the breast lies in its earlier recognition the value of this method of examination cannot be too strongly emphasized. It is urged that all roentgenologists acquaint themselves with the technique of the examination and use every opportunity to familiarize themselves with the characteristic as well as the abnormal breast changes.

[5] Holman, Emile. Cancer: The menace of repeated examinations. (Editorial.) *Surg., Gynec. & Obst.*, 1932, 55, 667–669.

THE AMERICAN CONGRESS OF RADIOLOGY

FROM September 25 to 30, of this year, there will be held at Chicago the first American Congress of Radiology. This will be an entirely new undertaking for American radiologists. As there seems to be some slight misunderstanding or lack of knowledge on the part of a few members of the American Roentgen Ray Society and the other radiological bodies as to the real aim and objects of this Congress, a few words in the way of explanation have seemed fitting.

Almost coincident with the first announcement that a Century of Progress Exposition was to be held in Chicago in 1933, a few loyal radiologists with the interests of our medical specialty at heart, conceived the plan of holding a combined meeting or Congress of all of our radiological bodies in conjunction with the Exposition. The four societies in this country, namely, the American Roentgen Ray Society, the Radiological Society of North America, the American Radium Society, and the American College of Radiology, appointed representatives to meet and formulate plans for such a Congress. Thus the four societies will act as the sponsors for the meeting. All radiological societies of North and South America will receive invitations for their members to attend.

The organization of the Congress is vested in an Executive Council composed of Dr. Benjamin H. Orndoff as Chairman, Dr. Edward L. Jenkinson, Secretary, Dr. Henry Schmitz, Treasurer, and Drs. James T. Case, Maximilian J. Hubeny, Byron H. Jackson, B. R. Kirklin, Leon J. Menville, Lawrence Reynolds, John T. Murphy, George E. Pfahler, and Albert Soiland. The Council elected Dr. Henry K. Pancoast as President of the Congress and appointed as Vice-Presidents the four Presidents of the Societies acting as sponsors,—Drs. John T. Murphy, Byron H. Jackson, Rollin H. Stevens and Albert Soiland.

Only members of the Council will act as chairmen of the ten Committees. Dr. Reynolds and Dr. Menville, the Editors of the two journals will serve as co-chairmen of the Committee on Publication, to ensure an equable distribution of papers presented. Dr. George E. Pfahler, Chairman of the Committee on Scientific Program, will have as his coworkers the secretaries of the three

purely scientific societies and the president or president-elect of each of the societies whose duty it will be to construct a 1933 program for his respective society. The Chairman of this important committee has asked for volunteers on the scientific program.

The scientific sessions of the Congress will be held in the Palmer House, Chicago, September 25 to 30, 1933. The scientific and commercial exhibits will be conveniently located in the same hotel.

It is planned to hold only morning sessions from 9 A.M. until 2 P.M., with two sections, diagnostic and therapeutic, meeting in separate rooms simultaneously, except that a joint meeting will be held on the first morning. This will provide ample opportunity for all members and guests to visit the Exposition in the afternoons and some of the evenings. Probably two evenings will be set aside for the Caldwell Lecture and the Janeway Lecture under the auspices of the American Roentgen Ray Society and the American Radium Society respectively, the convocations of the Radiological Society and of the College of Radiology. The permanent headquarters and business office of the Executive Council and Administration is 2561 North Clark Street, Chicago.

This Congress is a meeting in the interests of radiology as a specialty in medicine, as a means of collective research and as an exceptional opportunity to permit the public to learn something of the importance of radiology to mankind. Ever effort is being made to make this the greatest convention that has ever been organized for the benefit of the science of radiology. It must be fully realized that the existence of four societies has promulgated a healthy and friendly competition which has been largely beneficial, and it is earnestly hoped that this will be an opportunity for all of us to come together with a common interest—our specialty and the benefit to humanity.

Henry K. Pancoast
President, American Congress of Radiology

LAWRIE B. MORRISON
1875 - 1933

IN THE death of Dr. Lawrie Byron Morrison at his home in Brookline, Massachusetts, on January 16, 1933, from carcinomatosis, the American Roentgen Ray Society has lost one of its most talented and respected members.

Dr. Morrison was born in Barnet, Vermont, October 17, 1875. He was one of twelve children and his death is the first among them. His pre-medical education was obtained at Peacham Academy, and he received the degree of Doctor of Medicine from the University of Vermont Medical School in 1902. After an interneship in the Mary Fletcher Hospital in Burlington, he studied pathology in Montreal and Philadelphia. On his return he became instructor in pathology and histology in the University of Vermont Medical School. He practiced a short time in Burlington but was soon appointed Assistant Superintendant and Medical Director of the Mary Fletcher Hospital, holding this position for ten years. He married Fanny Rowe, who with his son, Harvey Rowe Morrison, a third year student in Harvard Medical School, survives him. In 1914 he came to Boston and was associated with the late Dr. Walter Dodd until Dr. Dodd's death in 1916.

Besides maintaining his own private laboratory, Dr. Morrison was roentgenologist at the following hospitals: New England Deaconess, New England Baptist, Faulkner, Corey Hill and Robert Breck Brigham, and was consulting roentgenologist to the Collis P. Huntington and Palmer Memorial Hospitals. He was a member of the Ameri-

can Medical Association, Massachusetts Medical Society, American Roentgen Ray Society, Radiological Society of North America, New England Roentgen Ray Society, American Society of Gastro-enterologists, Trudeau Society and the Boston Orthopedic Club.

Eminently fitted for roentgenology by his training as a pathologist and clinician, Dr. Morrison was an ideal consultant. He was deft, skillful and painstaking in his technical work. His wide experience, his unusual memory and his thorough study of his cases made him exceedingly accurate in diagnosis. He was not a narrow specialist but kept himself constantly informed in all branches of medicine, and his conscientious fidelity to his medical ideals won the admiration of all. While his rare executive ability aided him greatly in building the efficient organizations which he developed both in his laboratory and in his numerous hospitals, his success depended in no small measure on his own hard work. Though not endowed with a robust constitution he seemed tireless and was unsparing of himself in the pursuit of his investigations.

He was not a voluminous writer but he was deeply interested in research and scientific investigation. His papers were always clear and concise. He made a careful study of the cardia and lower esophagus, making

several reports of his findings and conclusions. His last paper on the "Study of the Hip Joint" is an excellent example of his patient, thorough and accurate observations over many years.

Though his professional ability and his scientific attainments were of the highest order, Lawrie Morrison will be best remembered for his personal charm, his self-sacrifice, his constant willingness to help others and his quiet and unfailing courage. To his patients he was always a gentle and sympathetic physician, so that it was truly said that every patient became his friend.

With the memory of Walter Dodd, who was also a victim of his profession, before him he knew the future only too well but was never heard to utter a complaining word or an expression of regret. His calm and quiet courage through the sufferings of the last year have been an inspiration to all who knew him.

With the members of his family, a host of friends sorrow because of his departure and hold him in affectionate remembrance for what he did and still more for what he was.

P. F. Butler

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. E. P. Pendergrass, University Hospital, Philadelphia, Pa.
Annual Meeting: Chicago, Ill., Sept. 25–30, 1933.

American College of Radiology
Secretary, Dr. Albert Soiland, 1407 S. Hope St., Los Angeles, Calif.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Section on Radiology, American Medical Association
Secretary, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio.
Annual meeting: Milwaukee, Wis., June 12–16, 1933.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y.
Annual meeting: Chicago, Ill., Sept. 25–30, 1933.

Radiological Section, Los Angeles County Medical Society
Secretary, Dr. D. R. MacColl, 2826 S. Hope St., Los Angeles, Calif.
Meets on the third Wednesday of each month at the California Hospital.

Radiological Section, Southern Medical Association
Secretary, Dr. C. H. Heacock, 20 S. Dunlap St., Memphis, Tenn.
Annual meeting: Richmond, Va., November, 1933.

Brooklyn Roentgen Ray Society
Secretary, Dr. G. W. Cramp, 921 President St., Brooklyn, N. Y.
Meets monthly on first Tuesday, October to April.

Buffalo Radiological Society
Secretary-Treasurer, Dr. Joseph S. Gian-Franceschi, 610 Niagara St., Buffalo, N. Y.
Meets second Monday of each month except during summer months, place of meeting selected by the host.

Chicago Roentgen Society
Secretary, Dr. George M. Landau, 660 Groveland Park.
Meeting second Thursday of each month October to May inclusive at Virginia Hotel.

Cincinnati Radiological Society
Secretary, Dr. H. G. Reineke, Christian R. Holmes Hospital, Cincinnati, Ohio. Meetings held monthly.

Cleveland Radiological Society
Secretary, Dr. M. A. Thomas, Medical Arts Bldg.
Meetings are held at 6:30 P.M. at the Cleveland Chamber of Commerce Club rooms on the fourth Monday of each month from October to April, inclusive.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital.
Meets monthly on first Thursday from October to May, at Wayne Country Medical Society Building.

Florida Radiological Society
Secretary, Dr. W. McL. Shaw, 418 St. James Bldg., Jacksonville, Fla
Meetings held twice a year, May and November.
Next meeting, Hollywood, Fla., May 1, 1933.

Illinois Radiological Society
Secretary, Dr. L. M. Hilt, Myers Bldg., Springfield, Ill.
Regular meetings held quarterly.

Indiana Roentgen Society
Secretary, Dr. J. N. Collins, Indianapolis, Ind.
Annual meeting each February 22 in Indianapolis.

Michigan Association of Roentgenologists
Secretary, Dr. S. W. Donaldson, St. Joseph's Mercy Hospital, Ann Arbor, Mich. Three meetings a year, Fall, Winter, and Spring. Next Meeting, University Hospital, Ann Arbor, Mich., May 27, 1933.

Milwaukee Roentgen Ray Society
Secretary, Dr. J. E. Habbe, 221 Wisconsin Ave., Milwaukee, Wis.
Meets first Friday in October, December, February and April. Place of meeting designated by the president.

Minnesota Radiological Society
Secretary, Dr. L. G. Rigler, University Hospital, Minneapolis, Minn. Next meeting, Rochester, Minn., May 22, 1933.

New England Roentgen Ray Society
Secretary, Dr. Thomas R. Healy, 370 Marlboro St., Boston, Mass.
Meets monthly on third Friday, Boston Medical Library.

New York Roentgen Society
Secretary, Dr. C. W. Schwartz, 33 E. 68th St., New York.
Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

Central New York Roentgen Ray Society
Secretary, Dr. H. S. Bull, 604 Masonic Temple, Auburn, N. Y.
Three meetings a year—January, May and November.

Pennsylvania Radiological Society
Secretary, Dr. W. E. Reiley, Clearfield, Penna.

Philadelphia Roentgen Ray Society
Secretary, Dr. Karl Kornblum, 3400 Spruce St.
Meeting first Thursday of each month from October to May inclusive, at 8:15 P.M., in Thomson Hall, College of Physicians, 19 S. 22d St.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. S. L. Warren, Strong Memorial Hospital.
Meets monthly on the first Friday evening at 7:45 at the Rochester Medical Association Building.

St. Louis Roentgen Club
Secretary, Dr. W. K. Mueller, University Club Bldg.
Meets first week of each month. Time and place of meetings designated by president.

South Carolina X-Ray Society
Secretary: Dr. R. B. Taft, 105 Rutledge Ave., Charleston, S. C.
Meets at time and place of South Carolina State Medical Association. Next meeting, Spartansburg, April, 1933.

Texas Radiological Society
Secretary-Treasurer, Dr. C. P. Harris, Houston, Texas.
Meets annually one day preceding the meeting of the Texas State Medical Association.

University of Michigan Roentgen Ray Society
Secretary, Dr. C. C. Taylor, University Hospital, Ann Arbor, Mich.
Meets first and third Wednesday evening of the month from October to June, at 8 o'clock in the amphitheatre of the University Hospital.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

Virginia Roentgen Ray Club
Secretary, Dr. Wright Clarkson, 205 S. Sycamore St., Petersburg, Va.
Meets annually in October.

Cuba

Sociedad Cubana de Radiologia y Fisioterapia
Secretary, Dr. Luis Fariñas, Animas 110, Havana, Cuba.
Meets monthly in Havana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Meets on the third Thursday of each month, from November to June inclusive, at 8:15 p.m., at 32 Welbeck St., London, W. 1., or as advertised.

Electro-Therapeutic Section of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month during the winter at 8:30 p.m. at the Royal Society of Medicine, 1 Wimpole St., London, W. 1.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Colin Macdonald, Lister House, 61 Collins St., Melbourne, Australia.
Meets monthly at Melbourne during the winter.

Section on Radiology, Canadian Medical Association
Secretary, Dr. A. H. Rolph, 160 St. George St., Toronto, Ont.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. P. C. Fenwick, The Hospital, Christchurch. Meets annually.

Continental Europe

Belgian Society of Roentgenology
Secretary, Dr. J. Boine, Avenue des Allies, 134, Louvain, (Belgium).
Meets monthly on second Sunday at d'Egmonds Palace, Brussels, except in the summertime.

Societe de Radiologie Médicale de France
Meets monthly on second Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean, La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse, Biel.
Meets annually in different cities.

Société Francaise d'Electrothérapie et de Radiologie Médicale
Meets monthly on fourth Tuesday, except during months of August and September, 12 Rue de Seine, Paris.

Association of German Roentgenologists and Radiologists in Czecho-Slovakia
Secretary, Dr. Walter Altschul, German University, Prague, 11/52.

Deutsche Röntgen-Gesellschaft (Gesellschaft für Röntgenkunde und Strahlenforschung)
Meets annually in April in different German cities, at least once in five year in Berlin. Meets in addition every two years with the Gesellschaft deutscher Naturforscher und Aerzte.
Permanent secretary, Professor Dr. Haenisch, Klopstockstrasse 10, Hamburg, Germany.

Dutch Society of Electrology and Roentgenology
Holds two meetings a year in Amsterdam, one in the Spring, and one in the Fall.

Societa Italiana Radiologia Medica
Secretary, Professor M. Ponzio, University of Turin, Turin.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Maracine 30 Bucarest, Rumania.
Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad, USSR, in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson.
Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A, Gusterin.
Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky.
Meets monthly on the first Monday at 8 o'clock, the place of meeting being selected by the Society.

Polish Society of Radiology
Secretary, Dr. Jan. Kochanowski, 45 Gornoslazka St., Warsaw. Meets annually.

Warsaw Section, Polish Society of Radiology
Secretary, Dr. B. Krynski, 11 Zielna St.
Meets once a month except in the summertime.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association. Each of the following societies, with exception of the Denmark Society, meets every second month except in the summertime.

Society of Medical Radiology of Sweden
Meets in Stockholm.

Society of Medical Radiology in Norway
Meets in Oslo.

Society of Medical Radiology in Denmark
Secretary, Dr. H. Scheuermann, Copenhagen.
Meets on the second Wednesday of each month from October to July in Copenhagen, at 8 o'clock in the State Institute of Roentgenology.

Society of Medical Radiology in Finland
Meets in Helsingfors.

Vienna Society of Roentgenology
Meets first Tuesday each month, October to July.

Orient

Japan X-ray Association
c/o Orthopedic Surgery, Tokyo Imperial University.
Meets annually in April.

Kinki Roentgen-Abend Society
Director, Dr. Prof. Taiga Saito, Ogawaoike, Kyoto, Japan. Meets bi-monthly on third Sunday.

MINNESOTA RADIOLOGICAL SOCIETY

The winter meeting of the Minnesota Radiological Society was held at the Nicollet Hotel in Minneapolis on Saturday, February 18, 1933, at 2:00 P.M. The following program was presented.

1. Preoperative Diagnosis of Malignancy of the Liver with Thorotrast. Lester G. Ericksen, M.D., Minneapolis.
2. The Physical Basis of Chest Radiography (Work of R. G. Wilsey) and the Ruggles Ciné-Cardiographic Film. Robert H. Morrison, Minneapolis.
3. A Simplified Technique for Roentgenography of the Optic Canals. John D. Camp, M.D., and Cesare Gianturco, M.D., Rochester.
4. Atypical Findings in Bone Lesions. Charles G. Sutherland, M.D., Rochester.
5. Roentgenologic Study of Bone Changes Accompanying Neurofibroma of the Spinal Cord and Associated Nerves. John D. Camp, M.D., Rochester. Discussion by W. A. O'Brien, M.D., Minneapolis.
6. Case Reports from the University Hospital.
   - A. Demonstration of Methylene Blue Method for Calibrating Roentgen-Ray Dosage. W. K. Stenstrom, Ph.D.
   - B. Achondroplasia, Advanced Ossification, Vertebral Osteochondritis. John B. Eneboe, M.D.
   - C. Carcinoma of Breast, Skeletal Metastases, Response to Radiation. C. O. Hansen, M.D.
   - D. Carcinoma of the Skin, Response to Radiation. Frederick B. Exner, M.D.
   - E. Simulants of Mediastinal Masses. Leo G. Rigler, M.D.

The Society was honored by the presence of Dean Richard E. Scammon of the University of Minnesota Medical School who delivered a very illuminating and stimulating address on "The Contributions of Radiology to the Study of Growth."

At the business meeting a resolution was adopted endorsing the principles of the Code of Ethics of the Philadelphia Roentgen Ray Society.

The next meeting of the Society will be held in Rochester, Minn., May 22, 1933.

Leo G. Rigler
Secretary

REUNION OF FRENCH PHYSICIANS

The Reunion of French-Speaking physicians practicing radiology and electrology (Medicine Electroradiologistes de Langue Francaise), under the auspices of the Société Francaise d'Electroradiologie et de Radiologie médicales, of the Société de Radiologie medicale francaise and of the Société Belge de Radiologie, to which are invited French-speaking physicians of whatever nationality, will be held in Paris, October 12, 1933, at the Faculty of Medicine at the same time as the Congress of Suggery.

The following questions will be the order of the day:

1. The roentgen examination of the mucosa of the large intestine. Reporters: Dr. Ledoux-Lebard, chief of service of medical electroradiology to the Hospitals of Paris, and Dr. Gilbert, medical radiologist of the Cantonnal Hospital of Geneva.
2. The short waves. Reporter: Profesor Réchou of Bordeaux, assisted by Drs. Auclair, Dausset and Drouet.

The officers of the congress are as follows: Belot, President; Delherm, Réchou and Dubois Trepagne, Vice-Presidents; Dariaux, Portret, Secretaries; Morel-Kahn, Treasurer.

THE ATMOSPHERE OF LARGE CITIES IN RELATION TO ULTRAVIOLET RAYS

The vapors contained in the air in large cities are often held responsible for the poor transmission of ultraviolet rays. To ascertain the degree of truth in the assertion, Dr. F. Ellinger recently carried out experiments on the roof of the Institut für Strahlenforschung and also at the meteorological observatory in Potsdam. This observatory offered practically rural conditions, whereas the Berlin institute, located between two railway stations in the center of the city, presented the most unfavorable condi-

tions imaginable. Nevertheless it was found that in Berlin, under the most unfavorable radiation conditions, the reduction of the intensity of the ultraviolet radiation, as compared with the values established in Potsdam, amounted to only 10 to 15 per cent. For the transmission of ultraviolet rays in large cities the skyshine is no less important than the direct solar radiation; in fact, in the winter months it exceeds, many times over, the direct radiation of the sun, while in summer it is of approximately equal value. Of greater significance is the fact that, at the Berlin institute, under the most favorable sun conditions, the intensity of the ultraviolet rays below in the court was only 10 per cent of the intensity of the rays established on the top of the building. The shady street, the gloomy court and dark rooms, together with the diet poor in vitamins, are the cause of the pale faces of city dwellers and the prevalence of rickets among their offspring. Ellinger recommends, as a means of obviating the condition, the more general introduction of roof gardens, the use of more suitable building material in the fronts of apartment houses, organized hikes of children in the parks or green fields, and the provision of sandpiles for children's play, as sand has a marked capacity to reflect ultraviolet rays. Ten minutes play outdoors in the sun will make up, in a general way, for the dearth of light during the hours in the schoolroom. The so much despised sandy regions near Berlin, with their many rivulets, offer especially favorable opportunites for exposing the body to intensive ultraviolet radiation. Overexposure to the sun's rays produces, however, a thickening of the horny layer of the skin, which impedes the passage of the ultraviolet rays into the deeper tissues of the body; hence, exaggerated exposure to solar radiation should be avoided. Treatment with artificial ultraviolet radiation, however, should not, Ellinger emphasizes, be undertaken by the public. He demands that light therapy be placed entirely in the hands of the physician and that lay treatment be prohibited because of the dangers.—*J. Am. M. Ass.*, Sept. 24, 1932, *99*, 1097.

INDIANA ROENTGEN SOCIETY

The sixth annual meeting of the Indiana Society was held in Indianapolis on February 22, 1933. Dr. E. R. Witwer of Detroit addressed the Society. The following officers were elected: President-elect: Dr. W. R. Cleveland, Evansville, Ind.; Vice-president: Dr. H. H. Inlow, Shelbyville, Ind., Secretary-Treasurer: Dr. James N. Collins, Indianapolis.

BOOK REVIEWS

Books Received Are Acknowledged under Heading: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

THE HISTORY OF DERMATOLOGY. By William Allen Pusey, A.M., M.D., LL.D., Professor of Dermatology Emeritus, University of Illinois; Sometime President of the American Dermatological Association, and of the American Medical Association. Cloth. Price, $3.00. Pp. 223, with 33 illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1933.

In this monograph of 223 pages, 9 chapters and 33 illustrations, the only work of its kind in the English language, Pusey has given to dermatology and to medicine an interesting, instructive, accurate and much needed outline of the history of dermatology. The work is dedicated to the younger generation which might lead one to assume that it is the young physician who will be most benefited by its perusal. In dermatology, as in all vocations, the beginner vaguely realizes that he is a legatee in the sense that he may easily and quickly acquire the sum total of human endeavor over a period of several thousand years; in other words, modern knowledge. As a rule, the beginner has neither the time nor the interest to ascertain how, why or when this knowledge was builded. This paucity of time and desire often continues until full maturity, with the result that there are many well-known dermatologists who know very little about the efforts and achievements of any but their contemporaries and immediate predecessors. There is now little excuse for complete historical ignorance. Pusey has written a concise history of the specialty that can be read in a few evenings. This would not be the case if Pusey, instead of writing this delightful historical summary, had elected to translate Iwan Bloch's "Geschichte der Hautkrankenheiten in der neueren Zeit," or Richter's "Geschichte der Dermatologie." The book is not a complete history of dermatology, but it does give all the major historical events. After reading the book one has an excellent general idea of how dermatology has been developed and by whom. Also, additional reading along these lines is suggested and stimulated by a large number of references. In this connection, the book ends with a most useful historical index.

A knowledge of the work of our remote and immediate predecessors tends to create a desirable spirit of humility. Pusey quotes from James Henry Robinson as follows:

"The human mind has then been built up through hundreds of thousands of years by gradual accretions and laborious accumulations. Man started at a cultural zero and had to find out everything for himself; or rather a very small number of peculiarly restless and adventurous spirits did the work. The great mass of humanity has never had anything to do with the increase of intelligence except to act as its medium of transfusion and perpetuation. Creative intelligence is confined to the very few...."

He also relates that when the mathematical genius, Abel, when asked how he had done so much work in the few years of his working life, answered: "By studying the masters." And Pusey commends in dermatology this advice of Abel's, to read the works of the masters.

The book is not a dry recital of historical events and details. It is a delectable narration in which the sequence unfolds naturally and smoothly. Short biographies and portraits of the great dermatologists of the past are given. The biographical sketches are written in such manner as to make the reader feel personally acquainted with the masters.

The story begins with the ancients. Then the evolution of dermatology is followed through the Graeco-Roman period, the medieval age and the renaissance, down to the modern period. The present phase of modern dermatology, since 1900, occupies the short last chapter. The author has wisely left an accurate and a permanent evaluation of this period to some future historian, but he discusses the modern trend and mentions the accomplishments of the early part of the period.

Throughout the book the relationship of dermatology and medicine is traced; and mention is made of the importance of the living skin in medical research which has led to so many discoveries in the fields of chemistry, biology,

morphology, immunology, physics, etc. Of fascinating interest are the development and far-reaching influence of the various schools and masters of dermatology so well described in this admirable work.

Dermatology, especially American dermatology, owes a debt of gratitude to Pusey for giving us this invaluable monograph. The book should be read, preserved and read again and again by at least every English speaking dermatologist.

George M. MacKee

La Tubercolosi dei polmoni e delle pleure. By Prof. Dott. Stefano Mancini, Medico Primario dell'Ospedale Civile di Livorno, Libero docente in Medicina interna nella R. Università di Siena, Libero docente in Tisiologia nella R. Università di Roma. Paper, price M. 50; bound, M. 53. Pp. 1135, with 90 illustrations. Sponsored by the Italian Association for the combat of Tuberculosis. Leipzig: Georg Thieme, 1933.

This is a very complete book in which pleuropulmonary tuberculosis is studied from every possible angle. The first two chapters consist of a bacteriological study of the different types of tubercle bacilli and of similar microorganisms. In the third chapter the genesis of the primary infection is dealt with very extensively, especially in regard to the transmission through breast feeding. The fourth chapter is dedicated to the study of the reaction of the body toward the infection including the various kinds of immunity and allergy. An extensive discussion of Ranke's theory is found in chapter five. Chapters six and seven deal with the generalization of the primary infection, chapter eight with the re-infection. Predisposition is discussed in the tenth chapter. Chapters eleven, twelve and thirteen deal with the normal anatomy of the lungs and with the various pathologic aspects of pulmonary tuberculosis. The clinical signs are given extensive description in the diagnostic section of the book and all known methods of examination (bacteriologic, immunologic, clinical, and roentgenologic) are discussed and evaluated. The last three hundred pages are dedicated to therapeutic measures. Finally the social aspects of the problem are considered and the measures adopted by the Fascist government in the combat of the disease are highly praised. This book may be well included in any physician's library as an excellent reference book on tuberculosis.

C. Gianturco

Physical Therapeutic Technic. By Frank Butler Granger, A.B., M.D., Late Physician-in-Chief, Department of Physical Therapy, Boston City Hospital; Director of Physical Therapy, United States Army; Medical Counselor, United States Veterans' Bureau. Revised by William D. McFee, M.D., Visiting Physician, Department of Physical Therapy, Boston City Hospital; Attending Specialist in Physical Therapy, United States Veterans' Bureau; Consultant in Physical Therapy, Ring Sanatorium. Second edition, revised. Cloth. Price, $6.50. Pp. 436, with 135 illustrations. Philadelphia and London: W. B. Saunders Company, 1932.

The first edition of this book was intended by the author for the general practitioner who has installed a limited equipment and of whom the Council on Physical Therapy of the American Medical Association said, "A physician who has installed a diathermy machine or an ultraviolet ray generator can do good in carefully selected cases with one of these methods. He is not, however, fully equipped to render physical therapeutics. As a rule, it is the careful combination of several physical agencies that gets the best results." One must consider that intention carefully since it means necessarily briefness of presentation—to say the least—in certain phases discussed in the text as, for example, hydrotherapy, mechanotherapy and muscle re-education. Granger died and we have before us a second edition which has been compiled and brought up to date by W. D. McFee. Here again the reviewer and reader must bear in mind the many difficulties of such a task, difficulties which to some extent and in some instances are almost insurmountable.

The theoretical principles of physical therapy are barely touched; electro physics, to quote an example, is limited to seven pages. The technique of application, however, is outlined in more detail and that, after all, is the purpose of the book. The reader is acquainted with the physiological effects produced by electricity, the principles of galvanic current, ionization, muscle testing and the various types of electrical current. Then follow a discussion of the electromagnetic spectrum, chapters on hydrotherapy, massage and the use of carbon dioxide

snow. The special technique used in the treatment of certain diseases covers over 80 pages. To mention only some of the conditions, we find arthritis, sciatica, neuritis, diseases of the circulatory system and pulmonary diseases, infantile paralysis, and many others, included in this list. A special chapter deals with physical therapy in diseases of the ear, nose and throat, which is written by G. B. Rice. The teaching of physical therapy and the organization of a physical therapy department in a hospital are also given consideration.

The critical reader will find a number of errors and omissions in the text; there is also room for argument in many places. While the scientifically thinking physician will be pleased to read on page 25 that the "stimulative effect of electricity is pure theory and as yet has no scientific evidence to support it," he may rightfully frown at the recommendation of "sterilization of tonsils temporarily by means of a vacuum or nonvacuum electrode or with the Curay ultraviolet light" (page 276).

The book being of a very personal nature has no bibliography. It is decidedly a practical guide for the beginner in physical therapy or the general practitioner who is desirous of having a laboratory manual within easy reach.

ERNST A. POHLE

Books Received

THE 1932 YEAR BOOK OF RADIOLOGY. Diagnosis, edited by Charles A. Waters, M.D., Associate in Roentgenology, Johns Hopkins University; Assistant Visiting Roentgenologist, Johns Hopkins Hospital. Therapeutics, edited by Ira I. Kaplan, B.Sc., M.D., Director Division of Cancer, Department of Hospitals, City of New York; Visiting Radiation Therapist, Bellevue Hospital, etc. Cloth. Price, $6.00. Pp. 750, with 498 illustrations. Chicago: The Year Book Publishers, 1932.

PAPERS RELATING TO THE PITUITARY BODY, HYPOTHALAMUS AND PARASYMPATHETIC NERVOUS SYSTEM. By Harvey Cushing, Professor of Surgery (Emeritus), Harvard University and recently Surgeon-in-Chief, Peter Bent Brigham Hospital, Boston. Cloth. Price, $5.00. Pp. 234, with 99 illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1932.

RADIOLOGIC MAXIMS. By Harold Swanberg, B.Sc., M.D., F.A.C.P., Editor, The Radiological Review; Radiologist, Saint Mary's Hospital and Blessing Hospital, Quincy, Illinois, etc. With a Foreword by Henry Schmitz, A.M., M.D., LL.D., Professor of Gynecology and Head of the Department, Loyola University School of Medicine. Cloth. Price, $1.50. Pp. 127. Quincy, Illinois: Radiological Review Publishing Company, 1932.

A TEXTBOOK OF SURGERY. By John Homans, M.D., Assistant Professor of Surgery, Harvard Medical School. Second edition. Price, $8.00. Pp. 1231, with 517 illustrations. With a special bibliographical index and with illustrations by Willard C. Shepard. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1932.

THE HISTORY OF DERMATOLOGY. By Wm. Allen Pusey, A.M., M.D., LL.D., Professor of Dermatology Emeritus, University of Illinois; Sometime President of the American Dermatological Association and of the American Medical Association. Cloth. Price, $3.00. Pp. 223, with 33 illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1933.

CHAPTERS IN AMERICAN OBSTETRICS. By Herbert Thoms. M.D., Associate Professor of Obstetrics and Gynecology, Yale University School of Medicine. Cloth. Price, $2.00. Pp. 90, with illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1933.

THE DIAGNOSIS AND TREATMENT OF POSTURAL DEFECTS. By Winthrop Morgan Phelps, B.S., M.D., M.A., F.A.C.S., Professor of Orthopaedic Surgery, Yale University, Orthopaedist-in-Chief, New Haven Hospital, Orthopaedic Surgeon, Yale University Department of Health, and Robert J. H. Kiphuth, Assistant Professor of Physical Education, Yale University, Head Coach in Swimming, Yale Athletic Association. Cloth. Price, $4.00. Pp. 180, with 108 illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1932.

MODERN ALCHEMY. By William Albert Noyes, University of Illinois, and W. Albert Noyes, Jr., Brown University. Cloth. Price, $3.00. Pp. 207, with 16 illustrations. Springfield, Illinois; Baltimore, Maryland: Charles C Thomas, 1932.

LA TUBERCOLOSI DEI POLMONI E DELLE PLEURE. Del Prof. Dott. Stefano Mancini, Medico Primario dell'Ospedale Civile di Livorno, Libero docente in Medicina interna nella R. Università di Siena, Libero docente in Tisiologia nella R. Università di Roma. Paper, price M. 50; bound, M. 53. Pp. 1135, with 90 illustrations. Leipzig: Georg Thieme, 1933.

LA TECHNIQUE DE LA CURIETHÉRAPIE. Par Simone Laborde, Chef du service de Curiethérapie a l'Institut du Cancer. Paper. Price, 20 fr. Pp. 118, with 12 illustrations. Paris: Gauthier-Villars et Cie, 1933.

LES KYSTES HYDATIQUES INTRATHORACIQUES CENTRAUX ET PARIÉTAUX; CHIRURGIE; RADIOLOGIE. Par. R.-G. Brun, Ancien interne des Hôpitaux de Paris, Correspondant National de la Société de Chirurgie de Paris, Chirurgien Chef de l'Hôpital Sadiki de Tunis, et A. Jaubert de Beaujeu, Chef du Service Radiologique de l'Hôpital Sadiki et de l'Hôpital Civil Français de Tunis. Pp. 9, with 42 illustrations. Paris: Norbert Maloine, 1933.

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, 105 Rutledge Ave., Charleston, S. C.

A NEW TECHNIQUE FOR ROENTGENOGRAPHY OF THE OPTIC CANALS*

By RAYMOND L. PFEIFFER, A.B., M.D.
NEW YORK CITY

THERE is no bony structure of greater importance to the ophthalmologist than the optic canal. Through this unyielding tube run the optic nerve and the ophthalmic artery. Here in a fixed space and held in contact are two structures subject to diverse diseases. Certain diseases of either, as tumor, aneurysm, or calcification of the ophthalmic and internal carotid arteries, may produce changes in the wall of, or within, the canal, and be detected by roentgenography. Those conditions which are primary in bone, or which result from fusion of bone or traumatism to bone, may affect the eye through the canal and be diagnosed by the roentgen ray. Diseases of the paranasal sinuses more frequently affect the canal and contained structures. The meninges, the circle of Willis, the hypophysis, and the cerebrum, are subject to diseases which may involve the canal and be detected by this laboratory method. So the roentgenologist can be of great service to the ophthalmologist by his ability to examine and give information concerning the canal and its relations.

ANATOMY

The optic canal is located just medial to the apex of the orbit and is formed by the fusion of the two roots of the lesser wing of the sphenoid with the side of its body. The floor extends posteriorly and the roof anteriorly, with the long axis varying from 4 to 9 mm. (Whitnall). According to Onodi, the canal may be as much as 12 mm. in length. The anterior opening is termed the foramen opticum, is oval in outline, and measures 5 to 6 mm. in its longer diameter. The central part of the canal is circular with an average diameter of 5.5 mm., and the posterior opening is generally considered flattened from above downwards (Whitnall). In roentgenography when a small focus tube and 25 inch target film distance are used, the diameter of the shadow of the canal on the film is approximately 1 mm. larger.

In the canal the optic nerve is enclosed in sheaths from the pia mater, arachnoidea and dura mater of the brain. The ophthalmic artery lies to the lower and outer side of the nerve in the dural sheath. Ossification of the fibrous septum thus formed between the nerve and artery gives rise to the rare abnormality of a double optic foramen. White has reported three such structures.

There is great variation in the relations of the canals. The roof or upper root of the lesser wing of the sphenoid is fairly strong and is occasionally pneumatized. Inferolaterally the inferior root of the lesser wing is thin, is rarely pneumatized, and is more rarely absent (Ledouble). This lower root separates the canal from the superior orbital fissure. On the medial side the canal is in relation to the sphenoidal sinus and occasionally to a posterior ethmoid cell. The canal may be surrounded entirely by sphenoid air space (Whitnall; Onodi). Onodi classifies 38 different forms and 12 groups of relations of the sinuses to the optic canal, thus indicating the extreme variation. The maxillary cells never lie near the canal. The frontal cells may extend to the canal roof.

* Read at the Thirty-third Annual Meeting, American Roentgen Ray Society, Detroit, Mich., Sept. 27–30, 1932.

Of greater clinical importance is the variable character of the bony walls separating the cells from the canal. These walls may be as thick as 5 to 7 mm. (Stanculeanu) or exceedingly thin, 2 mm. Dehiscences are reported and indeed seem to be not uncommon (del Duca; Holmes). Diploic venous channels passing from the air-cells to the orbital system of veins have been noted.

PRESENT METHODS OF ROENTGENOGRAPHY

The roentgenography of the canals is generally considered a most difficult procedure. In order that the film may be of diagnostic worth it is imperative that the canal be projected in true contour. This is difficult to achieve because of its anatomical position and construction at the apex of the orbit. The method of Rhese of projecting the ethmoid sinuses through the margin of the orbit and accidentally showing the canals was manifestly an unsatisfactory technique and led to the cap method of Goalwin. The results were thus improved, but it was a trial and error procedure. Technicians were unable to project the canals with consistent accuracy and after repeated effort and the expenditure of much time would frequently fail. The device of Argañaraz which consists of protractors and pendulums for finding the axes of the canals seems an improvement over the cap but not a solution of the problem.

THE PROBLEM AND ITS SOLUTION

The technical problems associated with the projecting of the canals are: (1) The finding of the angles; (2) the alinement of the primary pencil rays with the canal; (3) the fixation of the of patient's head; (4) the symmetry of projection of the two sides, and (5) making the projection consistently reproducible.

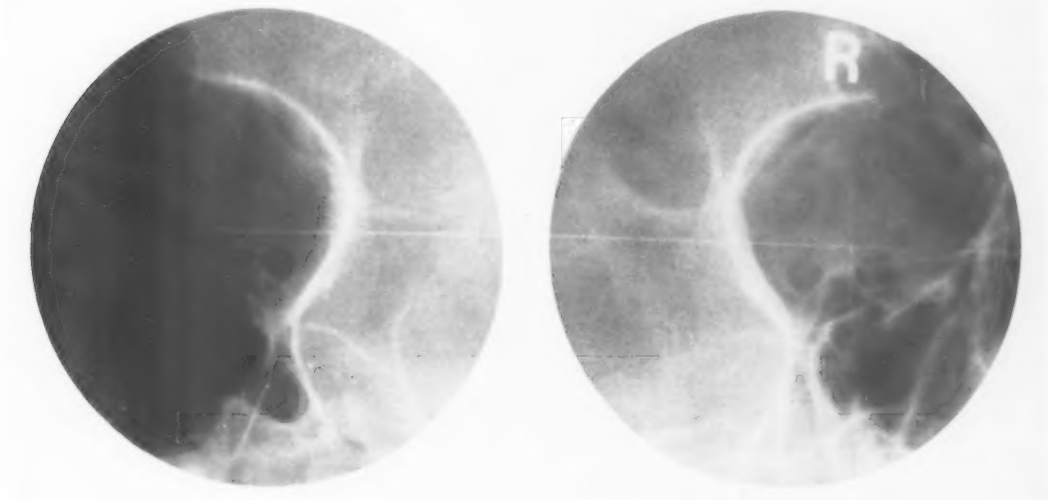

Fig. 1. The right and left optic canals symmetrically projected in the lower outer quadrants of the orbits. These are projections on one film of a pair of stereos.

The problem of the angles which the axes of the canals make with the principal planes of the skull has been well worked out. The angles commonly used were checked by roentgen study of dried skulls with the use of radiopaque markers in the positions of the canals and the planes. The angle which the axis of the canal makes with the median plane was found in different skulls to be approximately 37° and to be exceedingly constant (Fig. 2). That of the canal axis with the horizontal plane, in which lie the external auditory meati and

the inferior margins of the orbits (Ried's "base line"), is approximately 30° in the average adult skull and varies nearly 9° in

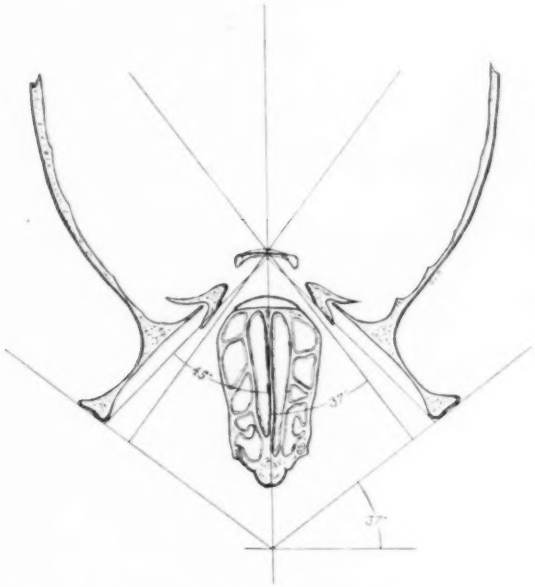

Fig. 2. A drawing of a horizontal section through the orbits and optic canals to illustrate the angles which are subtended by the axes of the canals with the median plane. The relation of the axes with the outer walls of the orbits is shown.

different skulls (Fig. 3). The degree and behavior of these angles in various skulls will be used in the device to be described, the one as a constant and the other as a variable.

This knowledge of the direction of the canal axis and the position of the canal is needed in order that the primary ray of the tube may be made to coincide with the axis and project the canal within the orbit and in true contour. Another essential is that the film be placed perpendicular to the ray. To study the effect of poor alinement of the primary ray with the canal the tube was focused properly at 25 inches and a dried skull placed in position and exposures made with the tube shifted to various points within a circular area of 3 inches in diameter, parallel with the film. As a result, the shadow of the canal in relation to the margin of the orbit was changed but slightly in the various positions with practically no distortion. It is considered that no greater error in the alinement of the tube than this area of 3 inches need result in the changing of the tube from one position to the other in the method given below.

To show the effect of various degrees of mal-alinement of the canal axis with the central ray, the tube was fixed in position and the skull changed to various positions and exposures made. The results showed that slight shifts of the skull caused great distortion and malposition of the shadow of the canal. It was also demonstrated that there is a latitude of projection in the lower outer quadrant of the orbit which will show the wall of the canal in accurate contour. The proper projection of the canal is in the center of this area. Inspection of the dried skull will verify the presence of this latitude.

To solve the problem of fixation, to obviate motion, and to secure symmetry of projection of the two canals, it was considered advisable to maintain the patient's head in one position for both canal exposures. The tube, then, would have to be shifted from one position to another for each canal. With this idea in mind the following device and technique were developed.

With the head in the prone position with face down, a tunnel was placed at an angle of 37° from the top of the table, to be perpendicular with the axis of the canal on one

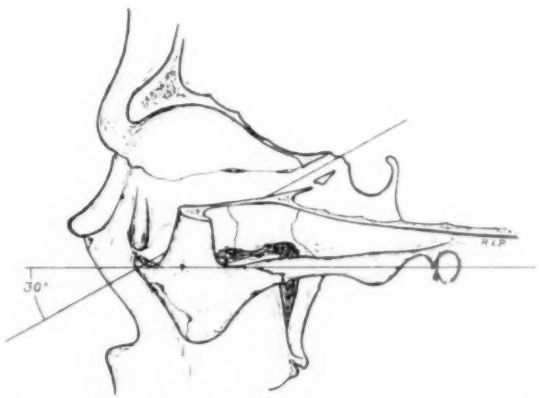

Fig. 3. A drawing to illustrate the angle which is subtended by the axis of the optic canal with the horizontal plane.

side. Another tunnel was inclined 37° on the opposite side and in the opposite direction to be perpendicular with the axis of the other canal. A "V" arrangement of the tunnels resulted (Figs. 4 and 5). Since this angle of the canal axis was found to be practically constant, the tunnels were fixed in the 37° position. To provide for the angle of the canal with the plane of Ried's "base line," 30°, an elevated rest or support was arranged for the patient's forehead when placed in the "V." But with this plan of procedure the variable factor of physiognomy had to be considered and the angle of 30° could not be used to establish the height of the support. This height depends on the length of the face as measured from the pogonion to ophryon, and on the shape of the forehead. The device was constructed and the height and position of the rest worked out experimentally to be 7 cm. for the average. Lines were then placed on the surfaces of the tunnels to locate the cross vertical plane (Fig. 4). Cross lines were then placed on these 7 cm. from the apex of the "V," as determined experimentally, to direct the focusing of the tube for alining the central rays. These lines were impregnated with white lead to indicate on the film the relation of the alinement of the canal to the alinement of the tube. Another line was placed horizontally and 5 mm. above the first (Fig. 5) to direct the centering of the patient's head. Finally, the tunnels were lined with lead with windows below, and closed above to protect half the film.

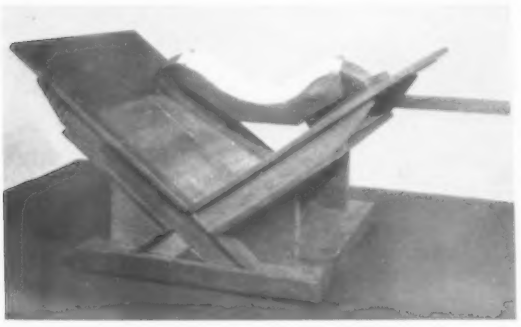

Fig. 4. The author's original device.

In order that the tube may be shifted from the right to the left side without moving the patient's head from position, a plumb bob was suspended from the tube

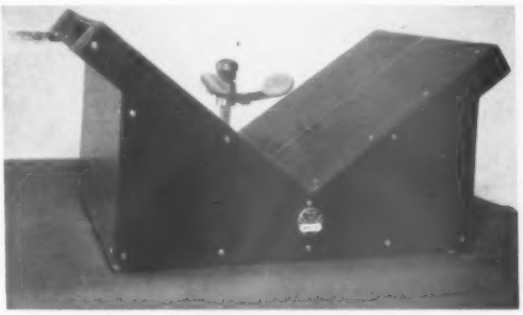

Fig. 5. A manufacturer's model.

carrier to measure on graduated arms attached to the tunnels the distance of the tube from the median plane of the skull for the projection of each canal (Fig. 6). By this arrangement a setting for one canal can be accurately duplicated for the other. The plumb bob may be eliminated by marking the positions of the tube on the table and always making the exposures from the same positions.

THE PROCEDURE FOR THE APPARATUS

In operation the procedure is as follows: (1) The device is placed on the roentgen table near to and straight with its edge (Fig. 6). (2) The tube of small focus is moved to the end of the carrier which is at right angles to the edge of the table, angled 37°, and the primary rays directed through a small cone at the cross marks on the left tunnel surface at a 25 inch target-film distance. (3) A reading of the plumb position on the right graduated arm is taken. (4) The patient is instructed to sit on a stool facing the table and to place his head in the apparatus. (5) The patient's chin is made to rest in the apex of the "V" and the forehead on the head support in a straight position with the canthi overlying the lines above the cross marks. (6) The cassette with 6.5×8.5 inch film is placed in the left tunnel and expo-

sure made. (7) Without moving the patient's head the tube stand is moved to the left side an equal distance from the median plane as indicated by the reading

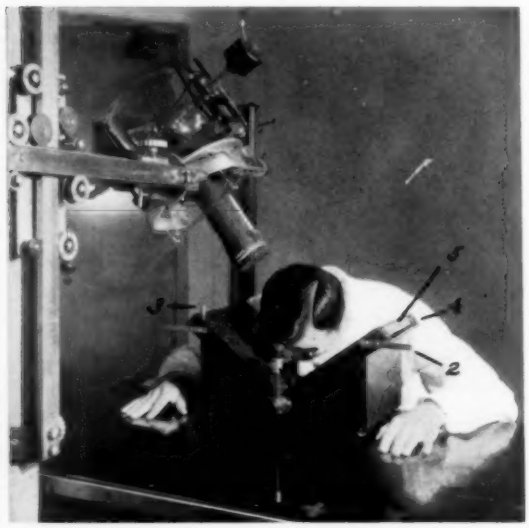

Fig. 6. The position for the projection of the left canal. 1. The adjustable head support. 2. The left graduated arm. 3. The plumb bob in position and indicating the tube setting on the right graduated arm for the projection of the left canal. 4. The left tunnel with cassette. 5. The lead lining of the tunnel.

on the graduated arm of that side, and the tube is angled 37° in the opposite direction. (8) The cassette is changed to the right tunnel with unexposed end down and the second exposure made. (9) The film may be labeled by placing the lead number on the corner and protecting the main part of the film with lead and making the exposure.

With the head support at an elevation of 7 cm. the canals of skulls which are within the range of normal variation, a number approximating 90 per cent, can be well projected. This support is adjustable and allows for the projection of skulls of extreme variation or deformity. Thus the apparatus is applicable for the roentgenography of the canals of all skulls.

This apparatus has been used extensively in skull studies at the Presbyterian Hospital, New York City, and routinely at the Neurological Institute for the past five months. The results have been quite uniform. The technique is exacting but not any more than for good skull roentgenography. The films show the canals to be projected in true contour in the lower outer quadrants of the orbits, to be symmetrically placed, and to be without evidence of motion (Fig. 1). The projections are reproducible.

Stereoscopic projections for study of the canals are of distinct advantage and may be made with the apparatus (Fig. 7). Beside the usual aid given by stereoscopic study further information may be gained from a projection to show the canal in a higher position in reference to the orbital margin and in relation to the superior orbital fissure. Such films may be made simply by the additional maneuver of shifting the tube in a manner parallel with the median plane of the skull after the primary alinement has been made, and changing the angle of the tube with the shifts to tend to center the rays on the cross marks of the tunnel.

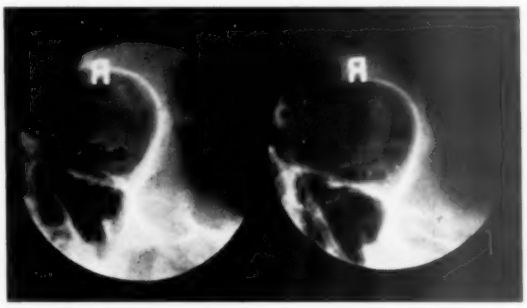

Fig. 7. Stereoscopic projections of one canal to show the position of each with their relations.

It may be observed that the Potter-Bucky diaphragm is not used; however, contrast is gained by using a small cone. While there is no need for the employment of the diaphragm, a simple device was made with the angles given above to be used with the grid of the roentgenographic table. This device was constructed as a mask to be strapped to the

patient's head. In practice the procedure for its use is to focus the tube perpendicularly at the junction of cross lines on the table, to place the patient in a prone position on the table with mask strapped to head and alined with the lines of the focal point, and then to make the exposure for the one side, using the diaphragm. The second exposure is made after the head and mask are turned to the other side and alined. Though quite successful this method is not as flexible and easily used as that described above. In view of the very satisfactory results obtained with the tunnel apparatus, it did not seem advisable to recommend the manufacture of the mask.

SUMMARY

1. The importance of the optic canal in ophthalmology is indicated. The anatomy and relations are briefly considered.

2. An apparatus for the roentgenography of the canals is presented. The device and method are founded on the principle of fixing the patient's head in one position and moving and changing the angle of the tube for the projections.

3. The method is simple, rapid, and accurate.

4. The canals are projected in true contour and symmetrically. The results are reproducible.

5. Stereoscopic projections may be made.

6. A method using the Potter-Bucky grid is also described.

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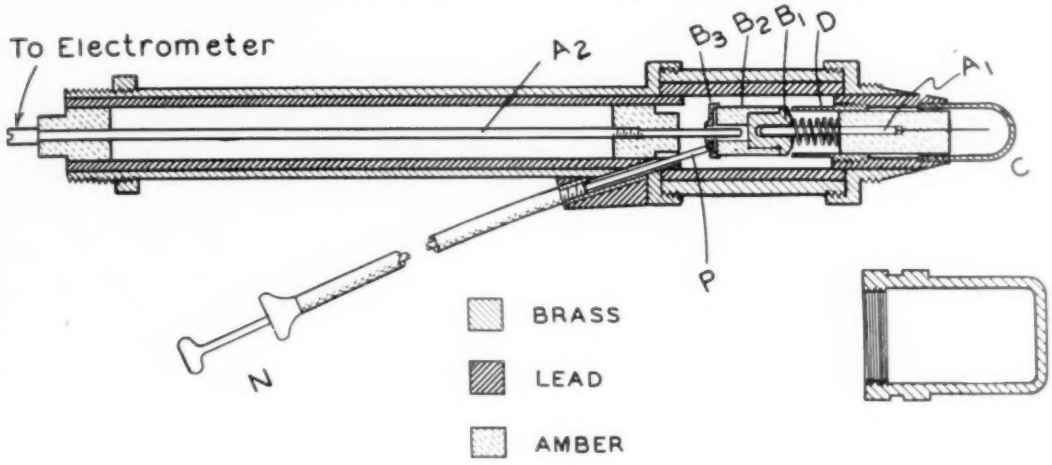
A REMOTELY OPERATED SWITCH FOR ROENTGEN DOSAGE METERS*

By LAURISTON S. TAYLOR *and* G. A. RHEINBOLD
Bureau of Standards, Washington, D. C.

IN connection with the use of several types of roentgen meters, as well as numerous laboratory problems, it has been found of great convenience to be able to control a charged electrometer circuit from a distance in order to avoid exposure of the body to roentgen rays or to facilitate the timing of operations. In the case of portable measuring instruments, a control switch of this type renders unnecessary special shutters on roentgen tube containers or the sudden throwing of power on a roentgen tube in order to properly time the exposure of a roentgen meter to the x-ray beam.



The accompanying diagram, showing the application of a remote control switch to a dosage meter, is practically self-explanatory. The conducting system, $A_1 - A_2$, from the thimble chamber is amber supported. Sliding on A_1 is the brass cap, B_1, upon which is mounted an amber cylinder, B_2, and a brass ring, B_3, having ample clearance around A_2 and insulated from B_1. The ring, B_3, serves simply as a bearing for the plunger, P, from an ordinary camera shutter release cable, by means of which the cap, B_1, may be allowed to contact A_2, thus connecting the chamber to the electrometer by a completely insulated system, or to contact D which grounds the conductor, A_1. It is important that the plunger, P, which is grounded, bear on a metal surface such as B_3 to avoid the frictional charging of the amber which would otherwise occur.

The release cord may be from 5–20 feet long and for convenience have a spring catch at N (not shown) for holding it in the grounded position.

As indicated in the drawing, the entire switch system is amply covered with $\frac{1}{8}''$ of lead overlapping at all joints for radiation shielding.

In use the plunger, P, is pushed in so that A_1 is grounded and no charge accumulates thereon. A_2 is then charged (in the case of a dosage meter) to a suitable potential and the chamber placed in working position. To expose the chamber the plunger is simply released for the desired time.

It should be noted that operation of this switch changes the capacitance of the system and a charge on A_2 is divided with A_1 in the ratio of their capacities. This necessitates, in the case of a roentgen meter, that the electrometer be charged to a fixed scale position beyond the desired zero, such that when A_1 is later connected into the circuit the resultant potential brings the indicator to zero. We have noted that, due to the absence of any frictional charging in the movement of B, the potential division repeats itself perfectly from time to time.

* Publication approved by the Acting Director of the Bureau of Standards of the U. S. Department of Commerce.

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ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

HEAD

Sosman, Merrill C. Xanthomatosis (Schüller-Christian's disease; lipoid histiocytosis). *J. Am. M. Ass.*, Jan. 9, 1932, *98*, 110–117.

Under the heading "xanthomatosis" are included five clinical entities, namely, Gaucher's disease, involving chiefly the spleen, Niemann-Pick's disease with hepatosplenomegaly, Schüller-Christian's disease involving especially the skeletal structures, xanthomatosis with cutaneous deposits associated with icterus, diabetes and pregnancy, and essential xanthomatosis.

Schüller-Christian's syndrome has been reported by various authors but Rowland first described the bone change as due to disturbance of the lipoid metabolism in connection with the reticulo-endothelial system. The bone defects are associated with exophthalmos, diabetes insipidus, gingivitis, hypoplasia and adiposogenital dystrophy. The diagnosis is essentially roentgenologic.

There is a tendency toward spontaneous remissions. Dietary measures, including low fat diets and various vitamins, have had variable success. Endocrine therapy has some beneficial effects on symptoms but is generally ineffectual. Roentgen therapy to the bone defects is uniformly beneficial, a dose of from one-half to two-thirds of an erythema producing definite healing of the bone lesions as well as reduction in severity of other symptoms. New lesions may later form in treated or untreated areas.

Six cases are reported making a total of 45 now is the literature.—*E. W. Hall.*

Bertel, G. Della localizzazione delle ombre intra ed extrasellari sulla base delle leggi di proiezione. (Localization of intrasellar and extrasellar shadows on the basis of the laws of projection.) *Arch. di radiol.*, 1931, *7*, 1021–1050.

Shadows within the skull may be projected into different locations depending on the inclination of the tube and the direction of the incident ray. Exostoses on the cranial bones, for example, may be projected into the sphenoidal cavity with the central ray perpendicular or above the sella with a strong cranial inclination of the tube. Shadows may appear to be osteomas of the sphenoidal sinus or calcifications within or above the sella depending on the position of the tube. Another law of projection that must be remembered by the roentgenologist is that when two objects lie one behind the other if the tube is displaced toward one side, the object closest to the focus will move more toward the opposite side than the one nearest the film. With an oblique projection the floor of the sella may appear to have a double outline and a shadow close to the floor may appear to be below it; generally this error can be rectified by finding the second outline below the object. Diagrams are given showing the displacement of objects according to the various laws of projection and illustrative cases are described. In general, an oblique projection of the sella is of greater diagnostic value than a perpendicular one. A complete examination requires one perpendicular roentgenogram and one moderately oblique one (10–15°) on each side. The inclination of the tube should be greater, the greater the distance between the focus and film as the amplitude of the displacement due to projection is inversely proportional to the distance between the film and focus.—*Audrey G. Morgan.*

NECK AND CHEST

Macklin, Charles C. The dynamic bronchial tree. *Am. Rev. Tuberc.*, March, 1932, *25*, 393–417.

The roentgen-ray method has been of particular service in bringing to light the details of respiratory bronchial movements, which are inseparable from functioning pulmonic tissue. Lengthening with widening occurs in inspiration, and shortening with narrowing in expiration. The bronchial and vascular "spokes" center in a "hub" or hilum, and in this there is an up-and-down shifting with respiratory movements, particularly obvious when breathing is forcible. This shifting is made necessary because of the inequality in the expansion of the pleural cavity, the lung having to move towards the expanding anterolateral walls and floor, and away from the upper paravertebral region, in inspiration, and reversely in expira-

tion. If this translocation is interfered with, from stiffening of the root, the ventilation of the region of lung lying above and behind the hilum is adversely affected, and it is possible that in such a condition, arising, it may be, in early life, we have an outstanding etiological factor in the propensity of tuberculous lesions to occur in the posterosuperior lung district. Diagrams are used to illustrate the points made.—*Author's abstract.*

Koral, Ephraim. The aetiology and mechanics of massive atelectasis. *Am. Rev. Tuberc.*, Sept., 1931, *24*, 276–284.

Massive atelectasis occurs only in patients confined to bed and is found, as a rule, in those obliged to recline in one certain posture. It can be prevented by frequent changes of posture.

In the recumbent posture the lungs are in a state of relative emphysema, and the force of inspiration is limited as the phase of inhalation begins with the lungs already largely inflated. In addition there is a diminished negative intrapleural pressure and the decreased amplitude of respiration in the recumbent position has a slowing effect on the venous circulation by diminishing intrathoracic suction. In the recumbent posture, expiration is facilitated, but the vital capacity of the lungs is diminished, due to the deficient power of inspiration. If expiration is interfered with, as happens following surgical incision of the abdominal muscles, the vital capacity will be still lower. In the supine position, there is a decrease of vital capacity of from 3 to 15 per cent. These factors favor the development of atelectasis, especially in the dependent and distal portions of the lungs. This disposition is especially noticeable in individuals with enfeebled musculature, in cachexia, in infants and in cases of general weakness following surgical shock. It is also seen following abdominal operations. The authors have also observed massive atelectasis in pulmonry tuberculosis, in general paralysis, in circulatory failure and as a complication of acute infectious diseases.

In prolonged recumbency on the side of the body, the recumbent lung becomes small and quite motionless and gives decreased resonance and feeble breath sounds, not unlike those of pleural effusion. Under such circumstances, pleurisy with effusion of empyema may be erroneously diagnosed. For differential diagnosis, the patient should be rolled over on the other side, as the atelectatic lung is thus likely to become inflated.

In the atelectatic lung, there is an accumulation of fluid in the air passages and in addition there is an accumulation of normal and abnormal secretions, because there is no expiratory air to propel the secretions toward the tracheal bifurcation. Patients who maintain one type of posture will frequently refrain from coughing or deep breathing, due to pain, weakness or other reasons, thus resulting in the accumulations of secretions, which secretions occlude other communicating bronchi and thus cause the collapse of new areas.

In massive atelectasis, dyspnea, cyanosis, rapid pulse and appearance of shock are the striking symptoms. The efficiency of the good lung is impaired by the functionless atelectatic lung, in that the respiratory passages in the latter add to the respiratory dead space. Under the fluoroscope, the affected lobe is seen to move upward with the ribs (paradoxical movement) and to become smaller with inspiration. During expiration, the lobe moves down and enlarges. The diaphragm may also go through paradoxical excursions. In the presence of adhesions preventing to and fro movement of the mediastinum, the paradoxical breathing will be less marked or even absent. Under such circumstances, massive atelectasis may occur without symptoms. Paradoxical breathing is only possible when the main bronchus of the atelectatic lung remains patent. When the accumulated secretion fills a large bronchus and overflows into a large bronchus of an adjacent lobe, it thus shuts off the entire latter lobe from respiration. It is at this time that examination discloses the physical and roentgen signs of atelectasis.—*M. L. Allen.*

Goldberg, B., and Gasul, B. M. Epituberculosis. *Am. Rev. Tuberc.*, Sept. 1931, *24*, 285–291.

Epituberculosis may be defined as a specific infiltration of a large area of lung tissue on an allergic basis, etiologically characterized clinically by subacute onset, mild symptoms and physical findings suggestive of consolidation, and characterized roentgenologically by a heavy, more or less homogeneous shadow density over the whole or greater part of the affected lobe. The mild onset, the benign course and the findings of consolidation are suggestive of the exudative and inflammatory processes incident to the phenomenon of allergy. Cases

are cited in which the infiltration of the lung followed a tuberculin reaction.

In a recent article, the authors presented 10 cases of epituberculosis which they had followed for over two years and from which they concluded that clinically these cases of epituberculosis represented a definite entity and that in the great majority of instances they can be diagnosed and differentiated from tuberculous pneumonias and chronic, nonspecific pneumonias. They state that pathologically epituberculosis may, in some cases, represent a nonspecific collateral inflammation, in others a large atelectatic area, and in still others the infiltrate may be a definite tuberculous structure which may go on either to calcification or to caseation and cavitation.

The authors report a case of epituberculosis in a colored child which they studied clinically and roentgenologically for a period of seventeen months and which died and came to autopsy. The physical and roentgen evidence pointed to an epituberculous involvement of the entire right upper lobe. The child was not acutely ill, however, and the physical and roentgen signs gradually improved. Following a tuberculin test, the patient developed a severe local, focal and general reaction, which caused an exacerbation of the disease, from which he died. The autopsy showed caseation of the right hilus lymph nodes, with erosions of the main branches of the bronchial tree, in the lower portion of the upper lobe. This caseation and spread gave rise to the occurrence of a generalized tuberculosis.

Epituberculosis is characterized by a subacute onset, with symptoms less than one would expect from the roentgen evidence of the disease. Under favorable conditions the lesion pursues a slow, gradual absorption.—*M. L. Allen.*

Fales, Lewis H., and Beaudet, E. A. The healing of tuberculous cavities. *Am. Rev. Tuberc.*, June, 1931, *23*, 690–701.

The authors, taking exception to Pinner's statement that the tuberculous cavity is the death sentence of the bearer, present a roentgen study of 120 suitable cases of pulmonary tuberculosis with cavitation. The progress of these cases was studied by means of stereoroentgenograms made at three-month intervals. The cases studied were all inmates of the U. S. Veterans Bureau Hospital at Livermore, California.

The authors assert that tuberculous cavities heal by a separation of the caseous necrotic tissue, which may be expelled by means of a bronchus or is absorbed. The walls of the cavity develop granulation tissue, which in time contracts and thus brings the walls of the cavities together. This may result in the formation of a scar, which may be demonstrable roentgenologically or may completely disappear. Occasionally a cavity may be shut in by a fibrous capsule, which may obscure the original cavity in the roentgenogram. These latter type of cavities were not included by the authors in their list of healed cavities.

All of the authors' cases which showed roentgen signs of healing were associated with clinical improvement, such as the sputum becoming negative, the disappearance of cough and the improvement of general well-being.

The authors classified the cavities they studied as to size and number only, as (1) small, less than 2.5 cm. in diameter, (2) large, diamter 2.5 cm. or more and (3) multiple, two or more cavities in one lung. The cases themselves were classified as minimal, moderately advanced and far advanced cases of tuberculosis, so as to show the effect of the amount of pulmonary involvement on the fate of cavities.

The studies showed that of the small cavities, 66 per cent healed and 18 per cent became smaller. Of the large cavities, 23 per cent healed and 45 per cent became smaller, while of the multiple cavities, 32 per cent healed and 21 per cent became smaller. In cases classified as minimal, 66 per cent of cavities healed, while in cases classified as moderately advanced, 61 per cent of cavities healed. In cases classified as far advanced, 30 per cent of cavities healed.

From their studies, the authors conclude that the ability of cavities to heal depend on two factors: (1) the size of the cavity and (2) the amount of pulmonary involvement. The rest treatment seemed to be of greater importance in the healing of cavities than artificial pneumothorax, thoracoplasty and other surgical measures. In bilateral cavitation, the prognosis is not good, as in only 9.3 per cent of these cases did the cavities heal in both lungs. In the above series of cases, it was found that where the patient's treatment was interrupted, 30 per cent of the cavities healed, while when hospitalization was continuous, 41 per cent of the cavities healed.—*M. L. Allen.*

Eloesser, L. Congenital cystic disease of the lung. *Surg., Gynec. & Obst.*, March, 1931, *52*, 747–758.

Eloesser believes that this condition is more common than is supposed. He was able to find only four observations in American literature published previous to this report; two by R. T. Miller, one by Pappenheimer and one of his own. The articles in the German and French literature relative to this condition were more numerous.

Congenital cysts of the lung occur in two forms: one, the solitary cyst, and the other, cystic disease proper with a more or less diffuse cystic degeneration of portions of the lung of various size.

Single solitary cysts lie within the parenchyma of the lung and may be small or occupy an entire lobe. Cysts which do not communicate with a bronchus are usually silent, being found merely as a coincidence. If there is communication with a bronchus and pus, instead of mucus, or air occurs in the cyst, the patient presents evidence of infection, and differentiation from empyema with a bronchial fistula is usually difficult.

The solitary congenital cysts are most frequently confused with other cystic collections as echinococcus, interlobar empyema, or with dermoids and similar solitary tumors. The difficulties of diagnosis of a single cyst may be great. Time, continued observation, constitutional signs of disease, complement fixation reactions in syphilis and echinococcus cysts, pulmonary tuberculosis elsewhere, aspiration and examination of the contents of the cysts and especially the findings at operation will usually solve the problem. The possibility should be borne in mind that any unusually obstinate large empyema cavity, which after operation shows no tendency to contract, may be not an empyema but a congenital cystic lung.

The second form, cystic disease proper, variously termed congenital bronchiectasis, honeycombed lung, etc., is possibly more frequent than the solitary cyst. In this form a whole or a part of one lobe, or even a whole lung may show various degrees of cystic degeneration, ranging from multiple miliary cysts scattered through a normal parenchyma to conversion of a lobe or of a whole lung into a huge multilocular or unilocular cystic sac.

Gramitz distinguishes two congenital cystic anomalies: a universal bronchiectasis in which a main bronchus and all its side branches are dilated so that the main one forms a large cyst with many small cysts debauching into it, and a telangiectatic bronchiectasis in which the smaller bronchioles are cystically dilated, the dilatation sometimes being open, sometimes closed, sometimes strung one after the other on the thread of an occluded bronchus like beads.

Recognition of cystic disease is not impossible in forms sufficiently severe to produce symptoms—in the milder ones, recognition is unimportant. In the infantile form, unexplained, recurring, severe attacks of cyanosis and dyspnea with signs simulating pneumothorax, displacement of the mediastinum, hyperresonance, and absent breath sounds will arouse suspicions which the roentgen ray may confirm. A shadow across the air-filled chest corresponding to an interlobar fissure will permit of differentiation of a dilated cystic lung from pneumothorax. Miller has reported cystic disease in infants. The symptoms are caused by a sudden distention of these congenital cysts with a displacement of the mediastinum and compression of the sound lung.

Cystic disease in the adult may remain silent as long as the cysts are sterile and filled with mucus or air. When infection supervenes they present the picture of a widespread bronchiectasis with cough, copious purulent sputum, dyspnea, sweats, and other constitutional symptoms. The chest wall of the affected side is retracted. The retraction probably takes place in early childhood.

Bronchoscopy may reveal anomalies of the bronchial tree.

The roentgenogram may show a single large annular shadow if the cyst is empty, or a more or less globular area of density if it is full of liquid. The density of a single cyst, especially if more or less pneumonic infiltration accompanies it, may be not round but quadrilateral or wedge shaped, resembling interlobar collections of fluid. When the cysts are empty, multiple cystic disease appears as a network of honey-comb or grape-cluster-like shadows occupying part or whole of a lobe or even a whole lung. When they contain fluid or are infected, separate cysts are usually indistinguishable in the uniform grayness of a surrounding acute or chronic pneumonic reaction. If the cysts communicate with a bronchus lipiodol injection demonstrates them beautifully, large or small areas of the lung field sprinkled with half-moon-shaped fluid levels. Larger dependent cysts may be

entirely filled. Cysts without a bronchial opening may be outlined in negative by the iodized oil which pours into the open bronchi surrounding them but leaving the cyst itself blank.

Multiple cysts of medium size are more easily recognized. Whether to consider them congenital or acquired, and the expression of true congenital cystic disease, or of a severe acquired bronchiectasis, is an academic question that lobectomy or autopsy even is not able to settle conclusively.

Three patients each with a whole lung connected into a series of pus containing sacs, the one apparently congenital, the second, syphilitic, the third, following an operation for hydrocele, presented exactly similar findings both at operation and in the roentgen examination. It is impossible to say whether the syphilitic and the postoperative ones had latent cystic disease made manifest by the implantation of infection, or whether the apparently congenital one was not like the others, acquired and the result of a sinusitis or some other hidden infectious process.—*J. H. Vastine.*

Wiberg, Gunnar. A case of aneurysm of the heart. *Acta radiol.*, 1931, *12*, 562–573.

The author briefly reviews the cases of aneurysm of the heart diagnosed by roentgen examination that have been reported in the literature, and concludes that aneurysms located at the apex or on the diaphragmatic surface of the heart are much harder to diagnose roentgenologically than those in other parts of the organ. He then describes a case of his own in which the aneurysm was not only correctly diagnosed by roentgen examination but was correctly localized at the apex of the left ventricle. Autopsy, however, showed another aneurysm higher up in the left ventricle that had not been diagnosed. This was contrary to the usual rule that aneurysms of the apex are harder to diagnose. The upper aneurysm simulated a very much enlarged left auricle. It is possible that if the examiner had thought of the possibility of its existence he might have succeeded in getting a clearer picture of it in some other projection.—*Audrey G. Morgan.*

Henry, A., and Jaubert de Beaujeu, A. La téléradiographie thoracique infantile en groupe. (Infantile thoracic teleroentgenography in groups.) *Arch. d'électric. méd.*, June, 1931, *39*, 193–204.

The authors used teleroentgenography for the simultaneous chest examination of a group of children, who were placed in a semicircle around a roentgen tube occupying the center. The radius of the semicircle, that is, the skin target distance, was 3 meters, the roentgen cassettes which the children were holding against their chests being arranged tangentially to the circle. It was found that the useful rays extended to the vicinity of 85° of both the left and right end of the semicircle. The technique of exposure was as follows: 200,000 volts, Coolidge air-cooled therapy tube, 1/30 of a second, the spark gap at the end of the tube amounting to 38 to 40 cm.

A total of 19 children five to seven years of age can be examined at the same time. The 27 cases of the author, however, were arranged in three groups of 10, 10 and 7 respectively. According to the findings obtained, they were classified into (*a*) normal, (*b*) doubtful and (*c*) diseased.

The advantage of the above method consists in the fact that a comparative roentgen study of the chests of several children can be made under exactly identical conditions. This has a certain value in periodical examinations of school children inasmuch as it permits a rapid classification and separation of those who need an attentive medical surveillance and a more thorough examination.

A brief résumé of the clinical histories and roentgen findings as well as reproductions of the roentgenograms in all 27 cases are included. —*T. Leucutia.*

ABDOMEN

Dall'Acqua, Virgilio. L'indagine radiologica del canale digerente mediante lo studio delle superfici mucose secondo il metodo del Berg. (The roentgen picture of the digestive tract shown by a study of the surface of the mucosa by Berg's method.) *Arch. di radiol.*, 1931, *7*, 1051–1071.

The ordinary methods of roentgen examination show the position, shape, motility and volume of the different parts of the digestive tract, their capacity for distention and the function of their walls, but they do not show the finer changes on the inner surface brought about by inflammation or the infiltration that takes place in the early stage of tumors. A method has been worked out of showing the finer configuration of the mucous membrane

by applying contrast medium in a thin layer so that it follows all the details of the mucous membrane relief. Berg and his school have perfected this method to such an extent that a roentgen examination of the digestive tract cannot be considered complete without it. The details of the technique for the various parts of the digestive tract are described and illustrative roentgenograms given.

By the use of this new method it is possible to demonstrate the various forms of gastritis roentgenologically, to show niches so slight that they are not shown by the ordinary method of distending the whole viscus with opaque paste, to demonstrate certain finer changes in ulcer such as the presence of "palisades" and convergence of the folds, to demonstrate tumors in the early stage and to determine the limits of the infiltration accurately.—*Audrey G. Morgan.*

Vischia, Quintino. Fistola digiuno-colica da ulcera digiunale in gastroenterostomizzat. (Jejunocolic fistula from jejunal ulcer after gastroenterostomy.) *Arch. di radiol.*, 1931, *7*, 1086–1093.

A patient of thirty-eight who had had a gastroenterostomy performed two years before for ulcer of the duodenum began to have intense abdominal pain. This had been preceded by diarrhea and loss of weight. From time to time there was eructation of gas and fecal matter. A diagnosis of jejunocolic fistula was made on this history and confirmed by roentgen examination, which showed the posterior gastroenterostomy opening functioning freely. The pylorus was pervious but only a small amount of paste passed through it. There was a jejunocolic fistula which became injected immediately and remained visible for several hours. It connected the efferent loop of the jejunum at about 10–12 cm. from the anastomotic opening with a vertical tract of the colon in the left half of the hypochondrium, probably the right branch of the splenic flexure. The fistula was 2 to 5 cm. long. There was an opaque niche about the size of a cherry on the anterior wall of the efferent loop of the jejunum where the fistula began. There was no pain on pressure over or around the niche. Six hours after the barium was given the stomach was empty but the whole colon was filled. Twenty-four hours later there were traces of barium in the stomach. Apparently there was retrograde passage of the opaque substance through the fistula into the stomach. As the first portion of the duodenum filled very incompletely it was impossible to say whether the old ulcer was healed or not. Surgical operation confirmed the diagnosis.—*Audrey G. Morgan.*

Hinton, J. William. Acute perforated ulcers of the stomach and duodenum. *Surg., Gynec. & Obst.*, March, 1931, *52*, 778–783.

The author's report covers 105 cases of perforated gastric and duodenal ulcers seen at Bellevue Hospital. Twenty-five of these died. Fifty-nine per cent of the 105 cases had a previous history of gastric symptoms. The average age of his cases was fifty-three. Of the 80 patients which survived, a second operation was necessary in 5 due to persistent symptoms. The author stresses the necessity of good postoperative medical supervision and occasional checking roentgenologically.

A routine examination of the teeth is made roentgenologically and sinus films are made when there is any indication, in an effort to exclude focal infection as a possible etiological factor.—*J. H. Vastine.*

Kirklin, B. R., and Broders, Albert C. Roentgenologic and pathologic aspects of gastric polyposis. *J. Am. M. Ass.*, Jan. 9, 1932, *98*, 95–99.

Two groups of polyps are described, the one consisting of polyps with individual bases and the other of polyps closely grouped and arising from a common thickened plaque-like base. Gastric polyps may be associated with polyps of the intestines. They are primarily benign but may become malignant.

Polyps usually produce symptoms of distress, anorexia, anemia and weakness, with loss of blood, which lead to a clinical diagnosis of cancer or ulcer. The final diagnosis is roentgenologic, for by careful study of the mucosal relief and filling defects as well as repetition of the examination to rule out food particles, the rather characteristic appearance of polyps can be found. Filling defects are smooth, and usually multiple. Peristalsis is undisturbed and the gastric outline is, as a rule, normal. Nineteen cases are discussed.—*E. W. Hall.*

Ochsner, Alton. Acute intestinal obstruction. *Surg., Gynec. & Obst.*, March, 1931, *52*, 702–712.

The diagnosis is made largely on the basis of the symptoms corroborated by the history.

In acute high intestinal obstruction a diagnosis should be made before the condition has progressed to such a degree that physical examination is of value. The diagnosis of mechanical ileus is usually not difficult if the condition is only considered by the surgeon. The history of intermittent, colicky abdominal pain is indicative of obstruction to a hollow viscus. If there is a history of previous laparotomy, the possibility of an "adhesion ileus" should be considered. The presence of external herniae, the contents of which cannot be reduced, would facilitate a diagnosis of mechanical ileus. Postoperative ileus may be of the adynamic or the mechanical variety. The diagnosis of an ileus developing postoperatively is relatively difficult. As repeatedly emphasized by Ochsner, a patient in whom an intestinal obstruction is suspected should receive nothing by mouth, especially no cathartics.

A valuable diagnostic procedure not sufficiently appreciated is the roentgenography of the abdomen without the administration of contrast substances. First advocated by Schwarz in 1911, this procedure has become popular in the European continental clinics, but, unfortunately, is used relatively infrequently in the United States. Case has, however, been instrumental in introducing this procedure into this country. As is duly appreciated by all surgeons, the administration of a contrast substance to a patient in whom an intestinal obstruction is suspected is not without danger. Not infrequently an incomplete obstruction may be transformed into a complete obstruction as a result of the administration of an opaque meal. In suspected obstructions of the large bowel, it is, however, permissible and at times advisable to examine the large bowel by means of a contrast enema. Roentgenography of the abdomen without the administration of a contrast substance is, on the other hand, entirely without danger. Because of the increased secretion and diminished absorption from the gut proximal to a mechanical obstruction or in the loops of the gut in adynamic ileus, there is an accumulation of fluid and gas within the gut. As emphasized by Schwarz, Assmann, Case, and others, the presence of abnormally large collections of gas in the small bowel are indicative of some obstruction. More significant, however, than the presence of gas in the intestine is the presence of numerous fluid levels in various parts of the abdomen, when the patient is examined in the erect position. The fluid contents of the intestine assume a dependent position in the loop of gut and are "capped" by gas in the same loop. As this occurs in several loops, such multiple fluid levels can be demonstrated in various parts of the abdomen. Such a roentgenogram is pathognomonic of ileus.—*J. H. Vastine.*

Grado, Giuseppe. Diverticoli del colon ed appendici epiploiche. (Diverticula of the colon and appendices epiploicae.) *Arch. di radiol.*, 1931, *7*, 1140–1145.

Diverticula of the large intestine do not cause any symptoms unless they become inflamed and in that case, as the symptoms of diverticulitis are not characteristic, a diagnosis may be made of colitis, cystitis, cholecystitis or appendicitis, depending on the site and size of the diverticula. But while they cannot be diagnosed clinically these diverticula can be demonstrated roentgenologically.

The author describes a case in a woman of forty-five who had had obstinate constipation since childhood. She came for examination for remittent fever, pain in the right iliac fossa and hemorrhoids. There was also a soft fluctuating swelling in the right iliac fossa. Three roentgenograms were made sixteen, twenty and twenty-four hours after a barium meal. The last two showed club-like diverticula along the whole course of the transverse colon, the first part of which was dilated, but the rest contracted until it was filiform. Such diverticula are often not visible when the intestine is dilated but when it is contracted as in this case they can be seen. Sometimes it is necessary to empty the colon in order to see them and in some cases they are hard to demonstrate because they are filled with feces or because their openings into the intestine are occluded.

Other cases of diverticula insinuated between the appendices epiploicae have been described. Such diverticula may be hernias of the mucous membrane through the musculature or they may be true diverticula made up of all three coats of the intestine. In this case there were probably changes in the musculature of the colon that had taken place gradually. As the transverse colon is covered throughout its course with peritoneum there is a point of least resistance at the attachment of the appendices epiploicae which are really only extroflexions of the peritoneum.—*Audrey G. Morgan.*

Mock, Harry E. Infective granuloma: Nonspecific chronic tumor-like productive inflam-

mations of the gastro-intestinal tract. *Surg., Gynec. & Obst.*, March, 1931, *52*, 672–689.

Infective granulomata are tumor-like masses influenced to a certain extent by a low grade, nonspecific infection and characterized by a piling up of granulation tissue showing varying stages of necrosis, fibroblastic changes, an true scar tissue or reparative tissue growth. The author discusses the nonspecific inflammatory masses occurring in the gastrointestinal tract The more familiar specific granulomata as the gumma of syphilis, and the hyperplasias of tuberculosis, actinomycosis and anthrax are not included.

The granulomata are usually sterile. The underlying cause being some interference with the blood supply.

The etiological factors which predispose to the formation of infective granulomata are: (1) conditions existing within the gastrointestinal tract itself or its mesentery, as diverticulitis, ulcers, polypi, erosions due to foreign bodies or hard inspissated feces, hyperplastic colitis, etc.; (2) extra-peritoneal infections which may gradually spread to and involve the gastrointestinal tract, such as infected lymph nodes, constriction of hernial sac, etc.; (3) trauma—surgical accidents or extraneous injuries. These include ligatures or sutures which constrict and act as local interference to the blood supply, or sutures which act as a foreign body, etc.

Symptomatology. (1) Inflammatory type, mild abdominal pain, nausea and vomiting and local tenderness. Fever seldom over 100°F. Leucocytosis 12,000 to 15,000 with polymorphonuclears predominating. History of chronicity.

(2) Obstructive type. The above findings in addition to cramp-like pains, constipation or obstipation.

(3) Constitutional symptoms—loss of weight; anorexia; neuroses; etc.

Roentgen examination usually reveals evidence of obstruction in the obstructive type, whereas this evidence is usually absent in the type giving inflammatory symptoms. Early roentgen examinations are frequently negative whereas later examinations in the same case reveal a defect or developing obstruction. The roentgen ray often only further confuses the diagnosis. On the other hand, escape of the barium into finger-like projections, pouches or pockets in the mass is very suggestive of granuloma. Care must be used in selecting cases for examination by the opaque meal since a partial obstruction may become complete.

The diagnosis most frequently made preoperatively in these cases is carcinoma. The roentgenologist should always bear this possibility in mind when the roentgen findings suggest carcinoma.

The treatment discussed is entirely surgical. In those cases in which surgical removal is not possible and with the favorable response of granulation tissue to irradiation in mind, the abstractor suggests this method of treatment as an alternative to complete surgical removal in selected cases.—*J. H. Vastine.*

Devois. Granulations miliaires péritonéales enregistrées radiographiquement. (Peritoneal miliary granulations shown roentgenographically.) *Bull. et mém. Soc. de radiol. méd. de France*, July, 1931, *19*, 324–325.

The author reports a case of Pott's disease with right-sided coxalgia in a boy twelve years of age who later developed an insidious pneumoperitoneal miliary tuberculosis. Roentgen films of the chest and abdomen clearly showed the presence of numerous miliary foci. The roentgen demonstration of miliary granulations within the abdomen is exceedingly rare, only one similar case having been found in the literature, that of Perotti, described under peritoneal calcicosis. In this case there was likewise a Pott's disease and it was assumed that the peritoneal calcicosis was the result of a direct extension of the tuberculosis from the abscess to the peritoneum. In the author's case there can be no doubt that the dissemination occurred on a hematogenic basis.—*T. Leucutia.*

Overholt, Richard H. Biliary tract visualization with radiopaque oils. *Surg., Gynec. & Obst.*, Jan., 1931, *52*, 92–97.

In this article the author shows the value of visualization of the biliary tract after operation by means of the injection of radiopaque oils. The knowledge derived from such a procedure is of value in determining the proper postoperative management of the case, such as determining the time for withdrawing the drainage tube and in giving a prognosis as to the probability of a persisting biliary fistula. The author bases his article on a study of 12 patients in the University of Pennsylvania Hospital, in all of which there was an injection of the biliary system with a radiopaque oil.

The method of injection is as follows: During the second or third week after operation the patient is placed on an adjustable fluoroscopic

table and the gallbladder drainage tube is then injected with 15 or 20 c.c. of campiodol (iodized rape seed oil). In a few cases brominol was used. Satisfactory visualization of the biliary tract was obtained with both of these media. In the presence of complete or partial obstruction of the common duct, the drainage tube was clamped following the injection and fluoroscopic examinations were made over a period of thirty to forty minutes. In no instance were there any untoward results following the injection.

In patients in whom no obstruction to the emptying of the common duct existed, the campiodol passed through the duct and into the duodenum. When an obstruction existed in the common duct, this duct as well as the hepatic ducts promptly filled and were clearly visualized. The position, contour and size of these ducts were clearly determined. Incomplete obstruction of the common duct was evidenced by a filling of the duct system with the expulsion of only a small amount of oil into the duodenum. In one case, the author was able to see rhythmical contractions of the gallbladder which continued after the patient was asked to stop breathing. In another patient the tortuosity of the cystic duct due the valves of Heister was clearly outlined. In cases in which common duct obstruction had existed for a long time, a dilatation of the hepatic ducts was demonstrated.

The article is well illustrated and the case reports are informatively written. From this series of cases, the author concludes that roentgenoscopic exploration of the biliary tract is of definite value after operation. It clearly determines the question of patency of the common duct and is an entirely safe procedure.—*M. L. Allen.*

Volicer, Ladislav. Die Leber und die Milz im Röntgenbilde. (The liver and spleen in the roentgenogram.) *Fortschr. a. d. Geb. d. Röntgenstrahlen*, Oct., 1931, *44*, 452–458.

By following the example of Radt the author has used at the Clinic of Dr. Pelnar, since the beginning of 1931, thorium dioxide sol (Heyden) for the visualization of the liver and spleen. He injects a daily amount of 10 c.c. (more recently 20 to 30 c.c.) intravenously without or with an equal amount of glucose solutions. The total dose amounts to 50 c.c. (5 injections of 10 c.c. or two injections of 25 c.c. each). No untoward effects were observed.

Ten cases in which the method was employed are briefly described and illustrated with roentgenograms. In one of the cases the author succeeded in associating the visualization of the spleen with a functional test, a maximum contraction of the spleen having occurred within twenty-five minutes and a decontraction within fifty minutes following the injection of adrenalin.

The conclusion is reached that the method has a certain clinical diagnostic value and that it is entirely harmless. The only disadvantage is the rather cumbersome dosage (10 c.c. daily) which after further improvement will no doubt be eliminated.—*T. Leucutia.*

GYNECOLOGY AND OBSTETRICS

Finley, Robert Kent. The diagnostic value of uterosalpingography in pre-adolescent ovarian torsion. *Surg., Gynec. & Obst.*, March, 1931, *52*, 723–731.

The author describes an ovarian tumor with torsion of the adnexa in a child nine years of age. The diagnosis was made preoperatively largely by uterosalpingography. The relative infrequency of a correct preoperative diagnosis is shown by the 19 similar cases collected from the literature in which a correct diagnosis was made preoperatively in only 2 cases. Three cubic centimeters of iodized oil were injected into the uterus and the diagnostic features of the examination were the spiral appearance of the tube, the crescentic displacement of the tube along the surface of the tumor and displacement of the uterus. Pneumoperitoneum combined with the uterosalpingography is of definite diagnostic value in these cases.

The author states that he would expect no untoward results from this procedure, and the value of the information gained would more than compensate for any inconvenience which the examination would cause the patient.—*J. H. Vastine.*

GENITOURINARY SYSTEM

Magnusson, W. On meteorism in pyelography and on the passage of gas through the small intestine. *Acta radiol.*, 1931, *12*, 552–561.

Marked meteorism is very common in pyelography. It is rapid in onset and there is more or less marked gaseous distention of the stomach also. For this reason the author concludes that the gas is swallowed air and that it does not come from chemical decomposition in the intestinal tract or from the blood by diffusion.

Investigation has shown that with the patient lying down, particularly on his left side, the gas rapidly passes into the small intestine. This explains why intestinal flatulence is more common in patients in bed than in those who are up. The author has studied the rapidity with which gas passes through the small intestine by inflating the stomach and filling the colon with opaque substance. He found that gas passes through the small intestine in about ten minutes and that with the patient in a favorable position it passes through the whole of the digestive tract in half an hour. In an experiment on himself in which he inspired air into the esophagus with the glottis closed the author found that about ¾ of a liter of air could be introduced into the stomach in three minutes. There is no reason therefore why this meteorism could not be due to swallowed air. Similar meteorism has also been seen in intravenous pyelography and attacks of renal colic. Meteorism due to swallowed air has been demonstrated in dogs at the same time with polyuria resulting from intravenous injection of glucose. It would seem therefore that the swallowing of air may be caused by impulses from the urinary tract. Swallowed air probably is the cause of meteorism in other circumstances than those discussed here.—*Audrey G. Morgan.*

Dourmashkin, Ralph L. The basis for management of ureteral calculi. *J. Am. M. Ass.*, Jan. 23, 1932, *98*, 276–283.

A stone may be lodged in a ureter for a considerable length of time without seriously hampering kidney drainage, marked hydronephrotic changes being rare during the first year of the disease. Urine may pass by stones of irregular shape or containing grooves and complete obstruction may occur when the grooves are clogged. Stones may also act in ball valve fashion to cause intermittent stoppage. Even with complete obstruction some kidneys seem to cease secreting temporarily, thus preventing hydronephrosis. Routine injection of opaque solutions is a dangerous procedure because of the liability of producing severe infection in the presence of stasis. Intravenous pyelography should be used in every case of stone impaction.

In acute cases cystoscopy and passage of a catheter is always indicated. A swollen mound may necessitate the use of fulguration.

In chronic cases intraurethral manipulation is indicated unless the stone exceeds 1.2 cm. in width if near the ureteral orifice or 0.8 cm. if in the upper ureter. The author's tunneled bougies or rubber bag catheters may be used to dilate the ureter or meatotomy may be indicated. Prolonged waiting is advisable in the case of stones situated low down and operation should be done on stones higher up only after several fruitless attempts at removal or when failure to move as noted by successive roentgenograms indicates encapsulation.—*E. W. Hall.*

SKELETAL SYSTEM

Bauman, George I. Absence of the cervical spine; Klippel-Feil syndrome. *J. Am. M. Ass.*, Jan. 9, 1932, *98*, 129–132.

The condition discussed is a marked anomaly of the spine rather than a true absence of cervical segments. The author adds 6 cases to about 30 found in the literature, his cases showing varying degrees of fusion, distortion and numerical absence of vertebrae. The patients exhibit a short neck, low hair line and limitation of motion. Variable symptoms are torticollis, mirror movement, facial deformity and disturbance in deglutition or respiration.—*E. W. Hall.*

Benedict, Edward B. Carcinoma in osteomyelitis. *Surg., Gynec. & Obst.*, July, 1931, *53*, 1–11.

The author reviews the entire literature relative to the occurrence of carcinoma in osteomyelitis, going back to the first published paper on the subject, which was written in 1833 by Caesar Hawkins of London, entitled "Cases of warty tumors in cicatrices." Since that time it has been recognized that carcinoma can develop in old ulcers and sinuses, but in recent years little has been written on the subject.

The author concludes that carcinoma is an exceedingly rare complication of osteomyelitis, only 12 cases having been found out of 2,400 cases of osteomyelitis treated in the wards of the Massachusetts General Hospital. However, in a large clinic, its occurrence should be borne in mind. In 5 of the 12 cases which the author cites, the carcinoma was obvious on physical examination, while in the other cases it was diagnosed either by biopsy or by subsequent pathological examination.

In the 12 cases cited, the disease was confined entirely to males, which is probably due to the fact that osteomyelitis is more common in the male sex. The tibia was involved in 8 of

the cases, the foot in 3 and the femur in one case. No cases of carcinoma were found developing in osteomyelitis of the jaw, humerus, radius and ulna, hand or other scattered locations. The typical history of these cases is somewhat as follows: A man of middle age or after enters the hospital because of foul ulcers or sinuses, generally of the lower leg, thigh or foot. Pain is a prominent symptom. Not infrequently there is a history of trauma preceding the onset of the osteomyelitis. Usually surrounding the fistulous opening there is a fairly definite cauliflower mass which leads to the diagnosis of carcinoma. In some cases, however, there may be no outward sign of malignant disease. In all suspicious cases a biopsy should be done and if carcinoma is found there is likelihood that the disease has spread inward along the tract and is involving the bone. Where there is no external evidence of malignancy, it may be impossible to make a diagnosis until the osteomyelitis cavity has been explored. In the few of the author's cited cases which were examined roentgenologically, it was not always possible to make a diagnosis of malignancy. The treatment in 9 of the cases was amputation and in 2 of the others a radical local excision of the growth was done. However, it seems wise to recommend amputation in most cases. The carcinoma in all of these cases is always of the epidermoid variety, indicating that it arises from the epithelium surrounding the sinus and grows inwardly along the wall of the fistulous tract. It seems probable that chronic irritation from the discharge of infectious material plays a part in the etiology of this type of carcinoma. As the disease is ordinarily of the slow-growing epidermoid variety and usually without metastasis to the groin, the prognosis under proper treatment is favorable.—*M. L. Allen.*

Porsio, Agostino. Studio radiologico sullo sviluppo della cavita sinoviale del ginocchio dell'uome. (Roentgen study of the development of the synovial cavity of the knee in man.) *Arch. di radiol.*, 1931, *7*, 1072–1085.

The synovial cavity of the knee joint was studied by injecting a suspension of barium sulphate and taking roentgenograms, using the bodies of fetuses from the third to the ninth mouth of intrauterine life and of individuals from birth up to eighty years of age. The synovial cavity of the knee in the fetus and infant is limited to the condyles of the femur. In the child and adult it extends beneath the quadriceps muscle. In the first two years of post-natal life the posterior part of the synovial cavity develops rapidly and forms the subpopliteal diverticulum. This diverticulum communicates directly with the suprameniscal and submeniscal parts of the synovial cavity. Sometimes it communicates directly only with the submeniscal part, of which it forms a diverticulum. Sometimes there are small diverticula in the anterior and inferior part of the synovial cavity which extend in front of the tibia. In the last two months of intrauterine life the submeniscal part of the synovial cavity extends farther forward than the suprameniscal part but in extrauterine life the suprameniscal part is more prominent than the submeniscal. In the adult the subpopliteal diverticulum is much more highly developed than it is in the infant. The weakest part of the synovial cavity is at the apex of the subquadricipital diverticulum. —*Audrey G. Morgan.*

Bozzetti, Giuseppe. Le esostosi cartilaginee multiple. (Multiple cartilaginous exostoses.) *Arch. di radiol.*, 1931, *7*, 1126–1139.

A patient aged twenty-seven was examined for tuberculous caries of the dorsal spinal column. He said that he had since childhood had hard nodules on the inner and outer sides of the condyles of the femur and tibia which had never caused any pain. Roentgen examination showed multiple cartilaginous exostoses at these sites on both sides and also at the upper metaphyses of both humeri. There were no congenital changes of the spinal column. Three of his brothers were then examined and all showed multiple cartilaginous exostoses of the femurs, tibiae and humeri. One of the brothers had been exempted from military service because the exostoses of the humeri interfered with the movements of his arms.

Roentgenograms taken during the period of growth in such cases show shadows much smaller than the excrescences felt on palpation, as only the centers are ossified and the peripheral cartilage is still transparent. Later after growth is complete and ossification has taken place the roentgen picture and the palpation findings correspond. When they are completely developed their structure is similar to that of normal bone. They may be entirely symptomless or they may cause pain and limitation of movement. They are evidently caused by a congenital anomaly in growth of the epiphyseal cartilages but the ultimate cause of this anomaly is not

known. Rickets and tuberculosis have been blamed and are frequently found in the history but they are not the ultimate cause of the condition.—*Audrey G. Morgan.*

Novati, G. Calchi. Su di un caso di cifosi dorsale degli adolescenti (Scheuermann) con sindrome psichica di Citelli. (A case of dorsal juvenile kyphosis (Scheuermann) with Citelli's psychic syndrome.) *Arch. di radiol.*, 1931, *7*, 1146–1160.

A case is described in a blacksmith sixteen years of age. He had a marked dorsal kyphosis extending from the 7th cervical vertebra to the first lumbar with the apex of the curve at the 9th to 10th dorsal. He had always been dull in school and had to repeat most of the grades once or twice. He was somnolent and became fatigued very quickly at his work. He had an adenoid facies, slept with his mouth open and snored. This was evidently a juvenile kyphosis of the Scheuermann-Schmorl type which causes a rigid spine and is brought about by changes in the intervertebral fibrocartilages. It almost always occurs in young persons who are doing hard physical work.

The psychic changes were those of the hypophyseal syndrome which Citelli says occurs in 70 per cent of cases of adenoids. The hypophysis is also known to affect bone growth, and the author suggests the possibility that both the juvenile kyphosis and the psychic syndrome in this case may have been caused by changes in the hypophysis brought about by the adenoids. —*Audrey G. Morgan.*

Burman, M. S., and Lapidus, Paul W. The functional disturbances caused by the inconstant bones and sesamoids of the foot. *Arch. Surg.*, June, 1931, *22*, 936–975.

The authors' study is based on a series of 1,000 roentgenograms of the foot. The number of patients was 596 and of these, 336 case histories were available for study. The following inconstant bones and sesamoids were considered: the os trigonum; accessory scaphoid or os tibiale externum; os perineum; styloid epiphysis and os vesalianum; os intermetatarseum; calcaneus secondarius (and calcaneonavicular fusion); os supranaviculare; secondary astragalus; os paracuneiforme; os subtibiale; bipartite internal cuneiform, bipartite cuboid, os proprium sustentaculi; cuboides secundarius, os unci; constant sesamoids of the great toe, and inconstant sesamoids of other toes. They think the name, inconstant bones, is more appropriate than accessory bones, since every one of these bones has a separate cartilaginous center, preformed in the human embryo as early as the second or third month of fetal life, as proved by Bardeleben and others. The majority of authors agree that these bones are to be considered as rudimentary elements inherited from the lower animals and present only in a more or less limited number of human feet.

Burman and Lapidus show a diagrammatic plan of the foot which shows the location of these bones when present, very clearly. Several of these, namely, the os supranaviculare and the secondary astragalus, are best seen in the lateral roentgenograms. The os trigonum has little functional significance. Fracture of the free os trigonum is rare and seems to be impossible. The so-called Shepherd's fracture (posterior fracture of the astragalus) is really only the free os trigonum. The consideration of symmetrical bilaterality is not an important point in the determination of fracture of the os trigonum. It is possible to find a fracture of a large posterior process of the astragalus, the detached fragment simulating a free os trigonum. Isolated disease of the bones is rare, one case of osteomyelitis having been reported. Occasionally arthritic disease may occur. Tumor of the os trigonum has never been reported.

Only the very large accessory scaphoid gives rise to functional disturbance of the foot. The local effects are due to the projection of the bone, medially or posteromedially. Surgical removal has sometimes been practiced. Fracture of the tuberosity of the scaphoid is rare but when it occurs, the detached fragment resembles the accessory scaphoid. Serration of the fragment or associated fracture of other bones are points that may be of service in the differential diagnosis. Arthitis of the line of articulation between the accessory scaphoid and the scaphoid is not unusual, shown in the roentgenogram by a haziness and irregularity of the joint surfaces. Epiphysitis of the accessory bone may occur. Tumor has not been reported. From the orthopedic standpoint the chief interest in the presence of the large accessory scaphoid is its relation to flat feet. The authors believe as a rule the accessory scaphoid should not be removed. Only the very large ones causing functional disturbance should be treated surgically by removal. Tumor has never been reported.

The os peroneum, wrongly called a sesamoid

in the tendon of the peroneus longus, has seldom been considered as a factor in the production of tarsalgia. Its bipartite character has often been noted. Burman and Lapidus draw attention to a syndrome, the patient complaining of sharp pain along the outer border of the foot, a variable distance behind the styloid process of the fifth metatarsal bone. They give a detailed account of all symptoms noted by them in 4 cases. The roentgenograms in these cases showed a multipartite os peroneum. They hesitate to call these cases fractures of the os peroneum. Isolated disease of this bone has not been described.

They consider that the question whether there is such a bone as the os vesalium has not been definitely answered. The styloid epiphysis of the fifth metatarsal is not the os vesalium. Diseases of this epiphysis are rare. Iselin has described an epiphysitis of this center. A short account of the controversy over the existence of the os vesalium is given, and the authors conclude that any practical importance attaching to the bone, if it exists, lies not so much in its rarity as in distinguishing it from fracture of the tuberosity of the fifth metatarsal bone.

The os metatarseum is located between the bases of the first and second metatarsals and this may make its visibility difficult in the roentgenogram. A dorsally placed bone may be seen occasionally in the lateral view, and should not be mistaken for an arthritic exostosis. Functionally it is relatively unimportant. It may sometimes form a dorsal and painful prominence.

The calcaneus secundarius becomes important in disturbing the statics of the foot only when fused, either by fibrous or bony union to both the navicular and the calcaneus—calcaneonavicular fusion. The symptomatology of such fusion is fully described; it varies with the degree and duration of the flat foot deformity which it causes. Burman and Lapidus believe a simple mechanical explanation is the best for the causation of this deformity.

The os paracuneiforme is located between the scaphoid and the inner cuneiform bone. Carlier and Cameron have described cases in which the bone was noted as a projection on the inner side of the foot. The os supranaviculare is located between the dorsal aspect of the scaphoid and the astragalus, usually articulating with the latter, though it may also fuse with the astragalus. It is to be differentiated from fracture of the superior surface of the scaphoid. The secondary astragalus is round and is located just behind and above the head of the astragalus. It may be fused or free and no functional disturbance is attributed to this bone. The os subtibiale is an unusual, pea-sized, accessory bone located on the medial aspect of the foot, just below the internal malleolus, anterior to the astragalar facet. It may closely resemble a fracture of the internal malleolus. It may be bilaterally present. The divided inner cuneiform and the os intercuneiforme have no functional significance.

The sesamoids of the great toe are sometimes the site of an osteochondropathy, but this as a clinical entity still rests upon insecure grounds. Congenital division of these sesamoids may occur. Fracture is not common. Arthritis is often seen, especially in connection with arthritis of the joint of the great toe. The arthritic exostosis may be joined to a similar exostosis on the second metatarsal. Periostitis of the sesamoids may occur. Osteomyelitis and tumor have apparently not been reported.

The authors conclude that changes due to the inconstant bones of the foot and the sesamoids are not many, but they are important in compensation work, especially in view of the fact that about 75 per cent of feet present such anomalies. The inconstant bones seldom disturb the statics of the foot.—*R. S. Bromer.*

Vogt, Edward C. Roentgenologic diagnosis of lead poisoning in infants and children. *J. Am. M. Ass.*, Jan. 9, 1932, *98*, 125–129.

Lead poisoning is considerably more frequent than usually supposed, being often unrecognized. The age of the patient is usually one to two years; the source of infection, paint from toys and woodwork; the symptoms, neurologic and gastrointestinal. The diagnosis is made from the history of a possible source of lead ingestion and the roentgenologic finding of a dense band in the growing portion of the bone. The band is more marked at the epiphyseal lines of the long bones and at the ends of the ribs. The width of the band is in proportion to the length and intensity of exposure to the metal. Complete resolution with disappearance of the dense bands results from proper treatment. Other heavy metals and phosphorus may give similar lines, but the chief error in diagnosis is to mistake the lead deposits for healed rickets. The clinical picture aids in differentiating lead poisoning from rickets.—*E. W. Hall.*

ROENTGEN AND RADIUM THERAPY

Paltrinieri, Giovanni. Roentgenterapia dell'idrocefalo cronico acquisito. (Roentgen therapy of acquired chronic hydrocephalus.) *Radiol. med.*, Dec., 1931, *18*, 1595–1613.

Seven cases of acquired chronic hydrocephalus treated by roentgen irradiation are described and illustrated by roentgenograms. Most of them improved clinically and some were even cured, but the intracranial pressure after treatment was almost exactly the same as it had been before. The author believes, therefore, that the effect of irradiation is not merely to regulate the production of cerebrospinal fluid but that it acts on the unknown cause of hydrocephalus which is probably an inflammation of some kind. The increased intracranial pressure is only a symptom of the inflammation, caused probably by exaggerated tonus of the meninges. The improvement after roentgen irradiation is due to the action of the rays on the inflammation and not to the mechanical effect of decreased tension. He believes, too, that the exaggeration of the digital impressions in hydrocephalus from serous meningitis is caused by an acute atrophy of the Sudeck type rather than by hypertension.—*Audrey G. Morgan.*

Gál, Felix. Über die Veränderungen des Grundumsatzes und des vegetativen Nervensystems bei den Funktionsanomalien der weiblichen Geschlechtsorgane und ihre Röntgenbehandlung. (Changes in basal metabolism and the vegetative nervous system in functional anomalies of the female sexual organs and their roentgen treatment.) *Strahlentherapie*, 1931, *41*, 559–599.

Typical cases of amenorrhea, oligomenorrhea, dysmenorrhea, metropathies, climacteric and premature climacteric, and operative and roentgen castration are described briefly. In women with amenorrhea and oligomenorrhea there are often changes in basal metabolism, most frequently an increase. In long-continued amenorrhea there is sometimes a decrease. In irreparable loss of ovarian function, as in castration, hypothyroidism seems to be frequent; if hyperthyroidism occurs it is apt to be transitory and amenable to treatment. An increase of true adrenalin sensitiveness is an almost constant symptom of this disturbance. The so-called substitution treatment is not always successful. Stimulant irradiation is more effective, and in hyperthyroidism thyroid treatment. Any improvement in general condition is accompanied by a change in the adrenalin reaction, but basal metabolism does not always become normal. Amenorrhea is often accompanied by sterility. It can frequently be overcome by diathermy.

In dysmenorrhea there is often a moderate increase of basal metabolism and adrenalin sensitiveness; if there is hyperthyroidism irradiation of the thyroid is effective. In juvenile metropathies there is often decrease or increase of basal metabolism and increased adrenalin sensitiveness. In cured cases basal metabolism very frequently returns to normal and adrenalin sensitiveness runs parallel with increase or decrease of the symptoms. The hemorrhage and nervous symptoms are often favorably affected by irradiation of the thyroid.

In the natural climacteric basal metabolism is often increased or decreased; there is no great change in adrenalin sensitiveness. Irradiation of the thyroid is an excellent treatment for the signs of loss of function. Hypothyroidism was found in cases in which operative castration had been performed a long time before; in one case there was severe Basedow's disease with great increase of basal metabolism. After roentgen castration there was often decreased basal metabolism but rarely any change in adrenalin sensitiveness. Immediately after irradiation basal metabolism was increased in several cases. In myoma, adrenalin sensitiveness and basal metabolism were sometimes increased even without treatment. This shows that the tumor itself may cause considerable changes in the organism.

From his experience the author divides disturbances of the female sexual organs into two groups. Permanent amenorrhea and operative and roentgen castration are characterized by a decrease of basal metabolism and hypothyroidism, while in oligomenorrhea, dysmenorrhea and juvenile metropathies an increase of adrenalin sensitiveness is characteristic. In the first group there is hypo-ovarianism which is generally accompanied by hypothyroidism; in the second group there is only ovarian dysfunction which may be accompanied by hypothyroidism but more frequently shows hyperthyroidism.

Adrenalin sensitiveness is a good indicator of endocrine condition, as it almost always changes with improvement or exacerbation of

the condition. Determination of basal metabolism is important in treatment as it shows the cases that can be influenced by thyroid treatment. For this reason it is important to determine basal metabolism in every case of disturbance of female genital function.—*Audrey G. Morgan.*

Zimmern, A., Chavany, J.-A., Brunet, R., and Schlissinger. Syndrome algo-asphyxique unilatéral des doigts avec gangrène cutanée débutante guéri par la radiothérapie de la région surrénale. (Unilateral algo-asphyxique syndrome of the fingers with beginning cutaneous gangrene cured by radiotherapy of the suprarenal region.) *Bull. et mém. Soc. de radiol. méd. de France*, June, 1931, *19*, 253–255.

The authors briefly describe a case which does not belong to the group of true Raynaud's disease, although the patient suffered intolerable pain for a period of several months localized to the ends of the fingers of the right hand with cyanosis and beginning superficial sphacelation of the end of the index and middle finger. Following semi-penetrating roentgen therapy over the suprarenal region (6 seances of 2 H per field, with 5 mm. Al every second day, the series being repeated two weeks later) there was complete alleviation of the symptoms with healing of the sphacelation.—*T. Leucutia.*

Zimmern, A., Berger, J., Paisseau and Porcher. Un cas particulierèment grave de thrombo-angéite oblitérante guéri par la radiothérapie surrénale. (A particularly grave case of thrombo-angiitis obliterans healed by suprarenal radiotherapy.) *Bull. et mém. Soc. de radiol. méd. de France*, June, 1931, *19*, 255–257.

This case represents a Buerger type of obliterating thrombo-angiitis in which suprarenal roentgen therapy (with a technique similar to that used above) led to marked benefit. Because of the very acute and progressive character of the gangrene, first an amputation was performed, but the stump failed to heal, the gangrene spreading upwards. Later roentgen therapy was instituted and after demarcation of the process a second smaller amputation led to complete healing.—*T. Leucutia.*

Zimmern, A., Chavany, J. A., and Brunet, R. La radiothérapie surrénale dans les gangrènes sèches. (Suprarenal radiotherapy in dry gangrene.) *J. de radiol. et d'électrol.*, July, 1931, *15*, 327–331. Also *Presse méd.*, July 15, 1931, *39*, 1061–1066.

As is well known, dry gangrene may occur in old age as a result of atheromatous lesions of the peripheric arteries and in young persons as a complication of diabetes, Raynaud's disease and especially of thrombo-angiitis obliterans or Buerger's disease. In the latter group unilateral suprarenalectomy, which has been practised for the past ten years, has often led to satisfactory results. Based on the same principle, the authors more recently employed roentgen therapy of the suprarenal region with some equally satisfactory benefit. There is often improvement immediately following the administration of the first treatment consisting in attenuation of the diffuse cyanosis, return of the rose color of the normal skin, warming up of the asphyctic region and rapid demarcation of the gangrene. In case of advanced necrosis roentgen therapy generally arrests the progress both on the surface and in the depth.

The technique is that described by Zimmern and Cottenot in 1912 for the treatment of hypertensions. In order to include the rich para- and prevertebral sympathetic plexus within the field of irradiation, two circular symmetrical areas are used, the roentgen beams being directed from backward forward and from outward inward with their axes intersecting in front of the lumbar vertebrae. The areas are 10 cm. in diameter, centered over the 12th rib; 130,000 volts, 5 mm. Al filter, 400 to 500 R on the skin per seance and per area, a series consisting of 4 seances, given over a period of 8 to 10 days, an interval of 15 to 20 days being allowed between the series.

The authors have treated 12 cases. Eight of these are briefly described in the text, some beautiful colored photographs being used for the illustration of the results obtained.

In analyzing the effect of the roentgen rays, the authors express the opinion that there must be an action both on the suprarenals and on the sympathetic system, the very intimate anatomic and functional liaison of these two systems being now well established.—*T. Leucutia.*

Didiée, J. Note sur les effets analgésiques des irradiations peu filtrées des carrefours vasculaires. (Note on the analgesic effect of lightly filtered radiations on the vascular quadrants.) *Bull. et mém. Soc. de radiol. méd. de France*, March, 1931, *19*, 88–93.

Functional sympathetic roentgen therapy for the analgesic effect has proved of great value. The author briefly enumerates 9 cases in which good results were obtained with the following technique: 30 cm. spark gap; 22 cm. skin target distance; 1 mm. Al; 250 to 300 R; 2 to 3 minutes; one to three seances at several days' intervals. The most commonly irradiated fields were the cubital region, axilla, popliteal space, triangle of Scarpa, submaxillary region, etc. It is advised that functional sympathetic irradiation be tried in every instance before resorting to sympathectomy.—*T. Leucutia.*

LANGERON, L., DESPLATS, R. and BÉRA, J. Documents cliniques concernant l'action de la radiothérapie de la région surrénale dans le traitement du diabète sucré. (Clinical documents concerning the action of radiotherapy of the suprarenal region in the treatment of diabetes mellitus.) *Presse méd.*, Nov. 21, 1931, *39*, 1709–1711.

The authors published several articles on the effect of roentgen irradiation of the suprarenal region on glycosuria and glycemia, giving therein their detailed technique of exposure (see former abstracts in this Journal). Since then it has been found that irradiation of other parts of the body leads to a similar effect, indicating that the action is most probably through the intermediary of the sympathetic system.

In the present article the authors briefly describe 11 cases, arriving at the following conclusion: roentgen irradiation of the suprarenal regions leads to decrease of the glycosuria in diabetes of moderate intensity whereas in the advanced cases in which acidosis has already set in the results are nil or the treatment may even lead to aggravation of the acidosis and glycosuria.—*T. Leucutia.*

BERTRAND and LABEAU. Rapport sur "le traitement radiothérapique de l'angine de poitrine." (Report on the radiation treatment of angina pectoris.) *Bull. et mém. Soc. de radiol. méd. de France*, March, 1931, *19*, 126–131.

Three methods are used for the treatment of angina pectoris.

(1) The method of Nemours-Auguste and Barrieu, which consists in the irradiation of the cardiac area through three fields of 10×10 cm., one anterior and two posterior, 25 cm. spark gap, 2 ma., 7 mm. Al, 30 cm. skin target distance, 20 minutes, three seances per week, one single field per seance. Later this method was somewhat changed by using five fields of entry: one, left second intercostal space, internal part; one, left fifth intercostal space, somewhat more laterally; one, right second intercostal space, internal part; one, third dorsal vertebra, and one, sixth dorsal vertebra.

(2) Method of Arillaga, which consists in the irradiation of the cardiac area through two fields of entry, one anterior and one posterior of 10×15 cm. each, the upper limit of the fields coinciding with the seventh cervical vertebra; 0.154 Å, 175 kv., 5 ma., 40 cm. skin target distance, 0.5 mm. Cu and 1 mm. Al as filters, daily seances, one field per seance, one series including six to ten seances, dose of 3.528 R per field. Repetition if necessary within forty days.

(3) Method of Marchal, which has a technique somewhat similar to that of Nemours-Auguste, except that the irradiation is commenced with short seances of 5 minutes, and gradually augmented until at the tenth seance the fourth per field it reaches 20 minutes; 25 cm. spark gap, 2 ma., 5 to 7 mm. Al, 30 cm. skin target distance, three fields, two anterior and one posterior, three seances per week, one field per seance.

Nemours-Auguste treated 51 cases, with 31 cures, 8 ameliorations, 5 failures, one incomplete treatment and 6 deaths during treatment. Arillaga treated 8 cases, with marked amelioration in every one. Marchal likewise reported amelioration in several cases.

The authors personally treated 7 cases, using the five-field method of Nemours-Auguste. A cure was obtained in 6 cases, the longest being of eighteen months' duration.

The conclusion is reached that roentgen therapy is of considerable value in the treatment of angina pectoris.—*T. Leucutia.*

DE DZIEMBOWSKI, S. Sur la valeur de quelques méthodes auxiliaires du traitement radiologique des néoplasmes et sur le role du traitement biologique. (On the value of some auxiliary methods of radiologic treatment of neoplasms and on the role of the biologic treatment.) *J. de radiol. et d'électrol.*, Oct., 1931, *15*, 561–564.

The number of auxiliary methods used in conjunction with radiation therapy of neoplasms is considerable. To take, for example, the chemical substances alone, not less than 250 preparations have already been used. The author has for several years endeavored to establish the effect of some of the auxiliary methods

on the results obtained by radiation therapy Thus he has tried diathermy, the injection of glucose, the application of arsenical and iodine preparations, the protein therapy (according to Werner), the local applications of fermentative substances (Pregl), the injections of autolysates of the neoplasms or of specific serums and the intravenous injection of isaminum ceruleum, but found that the results were quite uncertain.

Three years ago he started to use the autotransfusion or transfusion of blood preliminarily treated by roentgen rays, in conjunction with radiation therapy, the technique being as follows: 100 c.c. of blood is taken by puncture of the cubital vein in a glass container and a sufficient quantity of sodium citrate solution is added to prevent coagulation. After irradiation (with 150 r, 120 kv. max., 1 mm. Al filter, 3 ma., 23 cm. distance) the blood is immediately re-injected into the peritumoral region or, if possible, intratumorally. In case of deep-seated lesions, the injection is made subcutaneously or intramuscularly. Following this, radiation therapy is given in the routine manner.

The method has already been employed in about 130 cases and the results obtained were surprisingly good when compared with those of similar cases treated by irradiation alone. It is too soon, however, to form an opinion concerning the final outcome. Several theories are advanced to explain the effect on the tumor.—*T. Leucutia.*

Belot, J. Les méthodes mixtes dans le traitement des épithéliomas cutanés: Association du raclage, de l'électro-coagulation, de l'électrolyse et de la radiothérapie. (Mixed methods in the treatment of cutaneous epitheliomas: association of curettage, electrocoagulation, electrolysis and radiotherapy.) *J. de radiol. et d'électrol.*, July, 1931, *15*, 345–360.

Roentgen therapy alone leads to satisfactory results in a great number of the cutaneous epitheliomas, although rather large doses of penetrating and filtered rays must be used to bring about the complete resorption of the neoplastic elements. Certain epitheliomas, however, as for example, those containing pearls, and some intermediary forms are resistant to roentgen therapy. The same applies to postoperative recurrences and lesions previously treated with insufficient or poorly applied radiation. It seems that in all these instances the combination of roentgen therapy with certain other methods (this procedure being called by the author and Brocq the "mixed methods") leads to more satisfactory results.

During the past twenty-eight years the author has treated about 12,000 cases of cutaneous epitheliomas and from these he has gained the conviction that a single method is not sufficient in all instances but that a choice of several methods is often necessary.

The author proceeds as follows: If the lesion is superficial and not too extensive, the curette is applied first and this is followed by an irradiation with moderately penetrating roentgen rays (22 to 25 cm. spark gap) without filter, the dose varying between 15 and 25 H according to the case. If the infiltration of the neoplasm extends somewhat deeper, the dose is increased to 30 to 35 H and more penetrating roentgen rays (200 kv. with 0.5 mm. to 1 mm. Cu) are used. A single application suffices in the majority of instances. The cicatrization is rapid, being completed towards the twentieth day. In a certain number of cases a second dose of 6 to 12 H (25 cm. spark gap, 5 to 10 mm. Al filter), the so-called "consolidation" dose, is given within three weeks following the first treatment. Perfect cosmetic results are nearly always obtained, the percentage of final cures exceeding 85 per cent.

In very extensive or fungating infected epitheliomas, the above method sometimes proves unsatisfactory. The author, therefore, for the past three years, has used a new "mixed" method which consists in the preliminary administration of a dose of 5,000 R of penetrating roentgen rays (200 kv. and at least 1 mm. Cu filter), this being followed within eight days by curettage (under local anesthesia) and the immediate administration on the bleeding surface of a dose of 15 to 25 H (3,000 to 5,000 R) of moderately penetrating roentgen rays (125 kv.) without filtration. After cicatrization a last consolidation dose is given. The healing here is somewhat slower but the remarkable results obtained in some very stubborn lesions justify the method.

In a number of well-selected cases, the author combines curettage with electrocoagulation or electrolysis.

The conclusion is reached that the final success in the great majority of cutaneous epitheliomas depends primarily on the judicious selection of radiations and their association

with curettage and in certain instances with electrocoagulation and electrolysis.—*T. Leucutia.*

Halberstaedter, L., and Seiffert, A. Zur Radiumbehandlung des Kehlkopfkrebses. (Radium treatment of cancer of the larynx.) *Strahlentherapie*, 1931, *41*, 73–76.

The authors have previously made a report on their method of treating carcinoma of the larynx by cutting a window in the thyroid cartilage and applying the radium in that way. They have now increased their dosage from 7 mg. radium element to 10 mg. but have also increased the filter from 0.5 mm. platinum to 1 mm. platinum or gold. This weakens the soft gamma rays from 60 per cent to 36 per cent and the hard gamma rays from 95 per cent to 90 per cent. In some cases they even used 15 mg. radium with excellent results. In some cases late necroses developed but these occurred during an influenza epidemic and they think they were caused by the infection. They give a table of the results in 31 cases kept under observation after the end of treatment from twelve to twenty-three months. Five of the patients died of progressive carcinoma without improvement; these were very advanced cases; one is still living after twenty-three months with gland metastases, one died of grip pneumonia with necroses, 2 suffered necroses but recovered after total extirpation of the larynx, 3 suffered necroses but recovered after tracheotomy, one suffered necrosis which healed with stenosis for which tracheotomy was performed, one had necrosis but recovered without tracheotomy, while 17 were cured without any reaction.

They do not know whether the fenestration of the thyroid cartilage is absolutely necessary; it may be that the trauma involved in making the window increases the tendency to necrosis. In some cases in which the carcinoma had grown through the thyroid cartilage they did not make a window but applied the radium directly to the carcinoma. The case of this kind that they have observed longest is at least temporarily cured in spite of the fact that he had very extensive bilateral carcinoma; he has been free of symptoms for a year and a half and without necrosis. In later cases in which they have not made a window they have used an ivory or soft rubber plate about 1 cm. thick between the radium container and the soft parts; they think this should probably also be used in cases with fenestration. The problem of dosage is not yet solved and no routine treatment for carcinoma of the larynx can be given. In some recent cases they have used only 4 mg. to see whether it would decrease the tendency to necrosis.—*Audrey G. Morgan.*